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DRAFT FINAL

Corrective Action Plan for Expanded Bioventing System Site FT-03

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4-4 "Remove"
area



Charleston Air Force Base
South Carolina

Prepared For

Air Force Center for Environmental Excellence
Technology Transfer Division
Brooks Air Force Base
San Antonio, Texas

and

437 CES/CEV
Charleston Air Force Base
South Carolina

November 1996

 **PARSONS
ENGINEERING SCIENCE, INC.**

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**DRAFT FINAL
CORRECTIVE ACTION PLAN FOR
EXPANDED BIOVENTING SYSTEM
SITE FT-03
FORMER FIRE PROTECTION TRAINING AREA NO. 3
CHARLESTON AIR FORCE BASE, SOUTH CAROLINA**

**Prepared for
Air Force Center For Environmental Excellence
Brooks Air Force Base, Texas**

**And
437 CES/CEV
Charleston Air Force Base, South Carolina**

November 1996

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ACRONYMS AND ABBREVIATIONS

AFB	Air Force Base
AFCEE	Air Force Center for Environmental Excellence
AFFF	aqueous film forming foam
ARAR	applicable or relevant and appropriate regulations
AVG.	average
bgs	below ground surface
Bldg.	building
bls	below land surface
BTEX	benzene, toluene, ethylbenzene, xylenes
°C	degrees Celsius
CAP	corrective action plan
COC	chemical of concern
CO ₂	carbon dioxide
DIA.	diameter
ES	Engineering-Science, Inc.
ft	feet (foot)
ft/ft	foot per foot
ft ² /day	feet squared per day
HP	horsepower
IRP	Installation Restoration Program
mg/kg	milligrams per kilogram
MP	monitoring point
MPA	monitoring point A
MPB	monitoring point B
MPC	monitoring point C
MPD	monitoring point D
MPE	monitoring point E
MPF	monitoring point F
msl	mean sea level
O&M	operations and maintenance
O ₂	oxygen
PAH	polynuclear aromatic hydrocarbons
Parsons ES	Parsons Engineering Science, Inc.
PCB	polychlorinated biphenyls
P&ID	piping and instrumentation diagram
PID	photoionization detector
ppb	parts per billion
ppmv	parts per million by volume
PVC	polyvinyl chloride
RBC	risk-based concentration
RBCA	risk-based corrective action
RCRA	Resource Conservation and Recovery Act

RFI	RCRA facility investigation
RI/FS	Remedial Investigation/Feasibility Study
SAIC	Science Applications International Corporation
SCDHEC	South Carolina Department of Health and Environmental Control
scfm	standard cubic feet per minute
SCH.	schedule
SVOC	semi-volatile organic compound
SWMU	solid waste management unit
TBC	to be considered
TD	total depth
TKN	total Kjeldahl nitrogen
TPH	total petroleum hydrocarbons
TRPH	total recoverable petroleum hydrocarbons
TVH	total volatile hydrocarbons
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
µg/L	micrograms per liter
VMP	vapor monitoring point
VOC	volatile organic compound
VW	vent well

SECTION 1

INTRODUCTION

This plan presents the scope for an expanded bioventing system to conduct *in situ* treatment of the remaining fuel-contaminated soils at Site FT-03 (former Fire Protection Training Area No. 3), Charleston Air Force Base (AFB), South Carolina. A one-year bioventing pilot study previously conducted at this site had successful results in reducing fuel hydrocarbons in soils. Activities associated with the proposed system expansion will be performed by Parsons Engineering Science, Inc. (Parsons ES) for the Air Force Center for Environmental Excellence (AFCEE) Technology Transfer Division (ERT) under contract F41624-92-D-8036, 0017. The primary objectives of the bioventing system upgrade are to:

- Deliver oxygen to additional areas of the site that have subsurface soils contaminated with fuel hydrocarbons that did not receive treatment during the one-year pilot study;
- Provide additional characterization data that can be used for site closure;
- Continue *in situ* remediation of fuel-contaminated soils by injecting atmospheric air into the soils to promote aerobic fuel biodegradation processes; and
- Sustain *in situ* aerobic fuel biodegradation until hydrocarbon-contaminated soils within the unsaturated zone are remediated to below regulatory-approved standards.

During October 1992, a horizontal air injection vent well (VW) and four vapor monitoring points (VMPs) were installed on the north side of the burn pit to conduct a bioventing treatability study. From November 1992 through November 1993, an extended bioventing pilot test was performed at Site FT-03 to determine if *in situ* bioventing would be a feasible cleanup technology for the fuel-contaminated soils in the vadose zone. Due to the successful results of the one-year pilot test, the pilot-scale system has continued operation from the end of the one-year pilot test to the present time. As described in this work plan, system expansions are planned to remediate unsaturated soils on the south side of the burn pit. Further details on the pilot test procedures and results can be found in the *Draft Interim Bioventing Pilot Test Results Report for Fire Protection Training Area Site FT-03, Charleston AFB, South Carolina* (Engineering-Science, Inc., 1993).

Following the one-year pilot test, soil and soil gas data confirmed significant fuel contaminant reduction in the pilot test treatment area. Laboratory results from soil and soil gas samples showed significant reductions in total volatile hydrocarbons (TVH) in soil gas, and significant reductions in total recoverable petroleum hydrocarbon (TRPH) concentrations in soil. Concentrations of benzene, toluene, ethylbenzene, and xylenes (BTEX) in the soil and soil gas were initially low at the site. However, BTEX concentrations were reduced to nondetectable levels in all soil and soil gas samples that were collected at the end of the one-year pilot test. In addition, the one-year pilot test

demonstrated that significant oxygen utilization and biodegradation are continuing in the pilot test area and that continued bioventing will promote additional fuel biodegradation in the source area. Further details of the pilot test results are presented in Section 3. The success of bioventing at this site supports the recommendation of an expanded (full-scale) bioventing system as the most economical approach of remediating the remaining hydrocarbon-contaminated soils at Site FT-03. Although the expanded bioventing system will be designed to remediate soil contamination in the unsaturated zone, biodegradation of fuel hydrocarbons in vadose zone soils is expected to reduce BTEX loading in groundwater by removing the primary source of these contaminants. Bioventing will be used as a presumptive remedy to reduce the source of organic fuel compounds in groundwater and as a means to further reduce potential risks associated with contaminants at this site.

Pilot test data have been used to design the full-scale bioventing system to remediate contaminated soils. The expanded system will consist of the existing VW and one additional horizontal VW (to be constructed) to deliver oxygen to the remaining areas having fuel-contaminated soils. Six new VMPs will also be constructed to monitor contaminant reduction and oxygen influence adjacent to the new horizontal VW. Additional soil and soil gas sampling will be conducted during these installations.

This document is divided into eight sections including this introduction, and one appendix. Section 2 discusses site background and includes a discussion of existing characterization data. Section 3 provides the results of the extended pilot test conducted at Site FT-03. Section 4 identifies the treatment area of the proposed expanded system; provides construction details of the expanded system; and recommends a proven, cost-effective approach for the remediation of the remaining hydrocarbon-contaminated soils at the site. Procedures for handling investigation-derived waste are described in Section 5, and Base support requirements are listed in Section 6. Section 7 provides key points of contact at Charleston AFB, AFCEE, and Parsons ES; and Section 8 provides the references cited in this document. A design package for the expanded bioventing system is provided in Appendix A.

SECTION 2

SITE BACKGROUND

2.1 SITE DESCRIPTION AND HISTORY

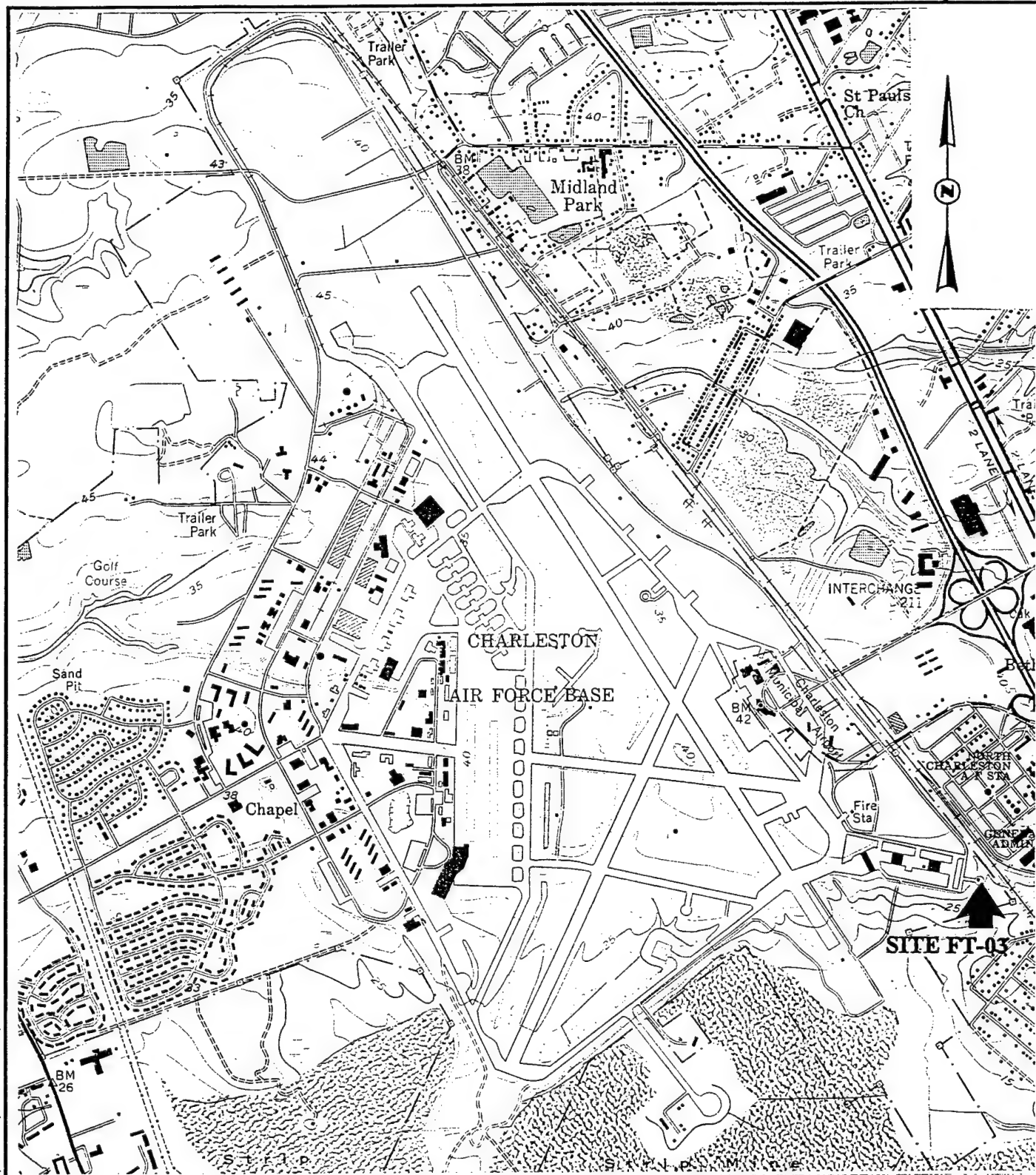
Fire Protection Training Area No. 3, also referenced as Site FT-03 and Solid Waste Management Unit (SWMU) #55, is located on the extreme southeastern part of Charleston AFB (see Figure 2.1). The 2-acre site was once used for controlled burning of flammable wastes during base fire training exercises. During its operation, the facility consisted of one burn pit surrounded by an earthen berm and lined with limestone gravel. A steel tank used as a mock aircraft was located inside the burn pit and a concrete building was located outside the burn pit on the southwest corner of the site. During fire training exercises, flammable liquids were sprayed on these structures and on the ground, ignited, and then extinguished using various agents such as aqueous film forming foam (AFFF), halon, and dry chemicals. It is reported that JP-4 jet fuel was the primary flammable liquid burned at the site; however, it is believed that other industrial wastes may have been burned when the facility was first established (Halliburton NUS, 1995). The site has not been used for fire training exercises since the early 1980's. It is currently overgrown and heavily wooded around its perimeter. The steel tank, concrete building, and remnants of the earthen berm are still present at the site. *phyto?*

2.2 PREVIOUS INVESTIGATIONS

A total of ten groundwater monitoring wells have been installed at Site FT-03. Seven of the groundwater monitoring wells were installed from 1985 through 1990 during two phases of remedial site investigations executed by Science Applications International Corporation (SAIC) and by Versar, Inc. As referenced by the Phase II Remedial Investigation/Feasibility Study (RI/FS) Report, Stage 2 (Versar, Inc., 1992), five of the original wells (3-1 through 3-5) reportedly had submerged well screens during several water level measuring events. Wells 3-6 and 3-7 were installed with screens reportedly above the water table. In addition to the monitoring well installation and sampling, other activities performed during this period included soil sampling, sediment sampling, surface water sampling, aquifer testing, and a soil gas survey. Total recoverable petroleum hydrocarbon (TRPH) concentrations as high as 7,770 milligrams per kilogram (mg/kg) were detected in shallow soils during these earlier investigations.

From 1992 through 1994, three additional monitoring wells (3-8, 3-9, B-7) were installed at the site by Halliburton NUS during a base-wide RCRA Facility Investigation (RFI). Well 3-8 was installed in between wells 3-3 and 3-6 to further delineate groundwater contaminants in the downgradient direction. Well B-7 was installed upgradient of Site FT-03 to monitor background groundwater conditions. Well 3-9, installed during 1994, was constructed as a deep well. This well was screened across the bottom 10 feet of the surficial aquifer to assess groundwater quality

Figure 2.1



Map Source: USGS (1958)
Ladson, South Carolina Quadrangle
(7.5 Minute Series)

2000' 1000' 0 2000'
Approximate Scale in Feet

Site Location Map

Site FT-03
Fire Training Area No. 3
Charleston AFB, South Carolina

near the base of the surficial aquifer. Halliburton NUS conducted additional soil, sediment, and groundwater sampling and aquifer testing during the 1992-1994 RFI.

Parsons ES conducted a one-year bioventing pilot test at the site beginning in November 1992. A horizontal vent well, regenerative blower, electrical power supply, and four vapor monitoring points (MPA, MPB, MPC, and MPD) were installed at the site to conduct the test. Results of the initial bioventing testing are presented in the *Draft Interim Bioventing Pilot Test Results Report for Fire Protection Training Area Site FT-03, Charleston AFB, South Carolina* (Engineering-Science, Inc., 1993). Details of the bioventing test are discussed in Section 3 of this report. Figure 2.2 shows the locations of existing site features, monitoring wells, and pilot test installations presently located at Site FT-03.

2.3 SITE GEOLOGY AND HYDROGEOLOGY

A more detailed discussion of the site lithology and hydrogeology can be found in the *Draft Interim Bioventing Pilot Test Results Report for Fire Protection Training Area Site FT-03, Charleston AFB, South Carolina* (Engineering-Science, Inc., 1993), and the *Draft RCRA Facility Investigation Report, Charleston AFB, South Carolina* (Halliburton NUS, 1995). Charleston AFB is located in the Lower Coastal Plain physiographic province of South Carolina. Sediments beneath the base are characterized as a thick sequence of interbedded sands, silts, and clays formed by fluvial and marine processes. These interbedded layers are grouped into regional formations and aquifers based on lithologic and water quality characteristics. Surficial soils around the base are generally sandy and highly permeable at shallow depths, but may contain zones of clay and organic deposits. The area is marked by low geomorphic relief.

The subsurface lithology was characterized across the site during previous investigations (Halliburton NUS, 1995). The shallow subsurface material was identified as part of the Ladson Formation, which consists of a fine to medium-grained sand with traces of silt, intermittent clays, and some clay stringers. Figures 2.3 and 2.4 show two hydrogeologic cross sections of the site developed by Halliburton NUS (1995). The Cooper Marl Formation forms the base of the surficial aquifer, and was identified in borings at the site from 38 to 55 feet below ground surface (bgs). Unsaturated soil in the vicinity of Site FT-03 are primarily silty sand with traces of silt and clay. Fill material consisting of silt, sand, and crushed aggregate was encountered within the berm that surrounds the burn pit (Halliburton NUS, 1995). Remnants of the berm, which was constructed of soil and limestone aggregate, are still present at the site. The berm hinders surface drainage from the burn pit and the pit often contains several inches of standing water after precipitation events.

Groundwater in the surficial aquifer is encountered at an average depth of 4 feet bls in the vicinity of the burn pit on Site FT-03. The surficial aquifer consists of a silty sand matrix. Precipitation is the primary mode of recharge at the site. The water table fluctuates in response to precipitation and shows seasonal elevation changes. After extended periods of precipitation, the water table has been observed as shallow as 2 feet bls in the burn pit area (Engineering-Science, Inc., 1993).

Figure 2.2

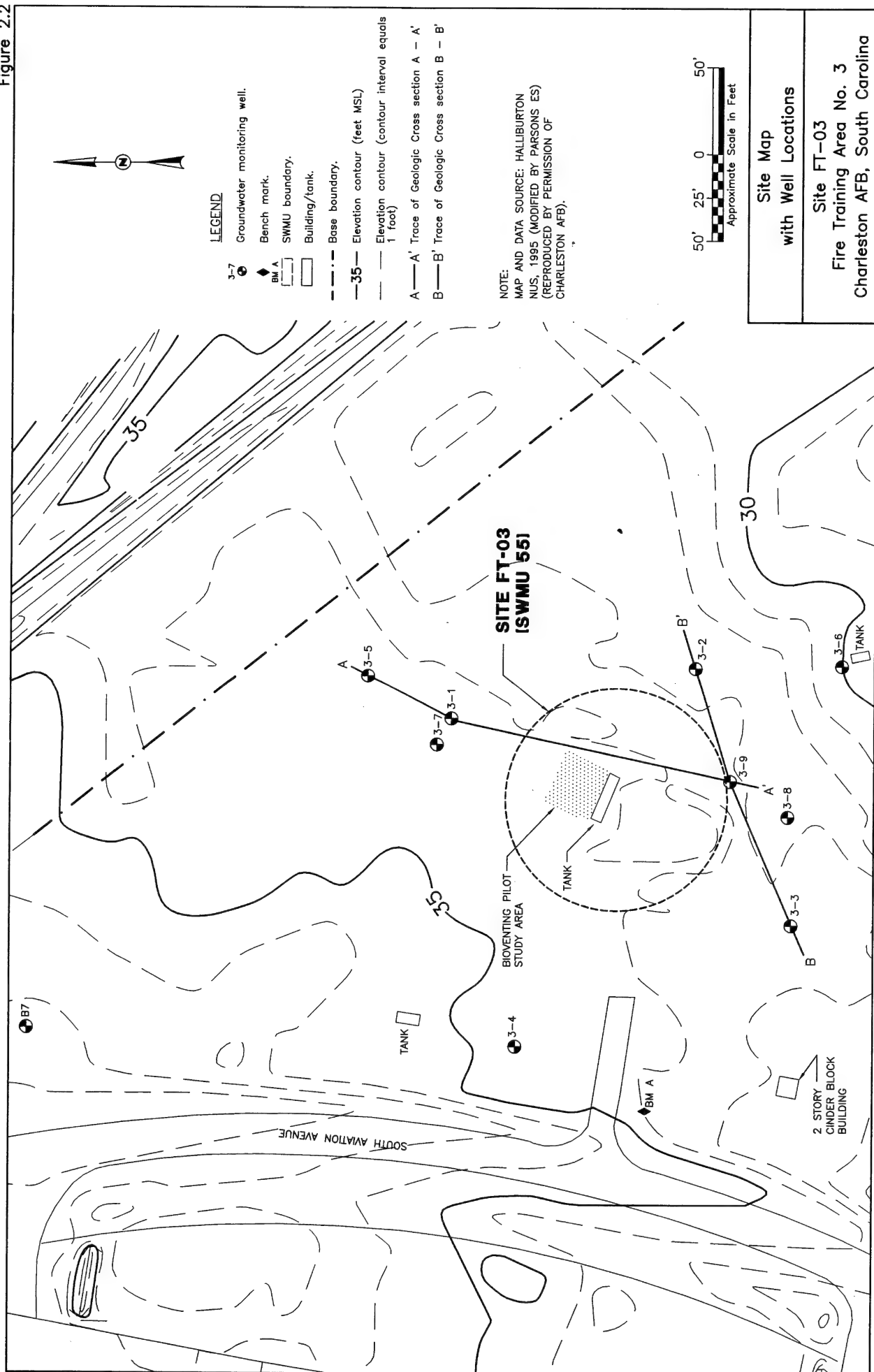
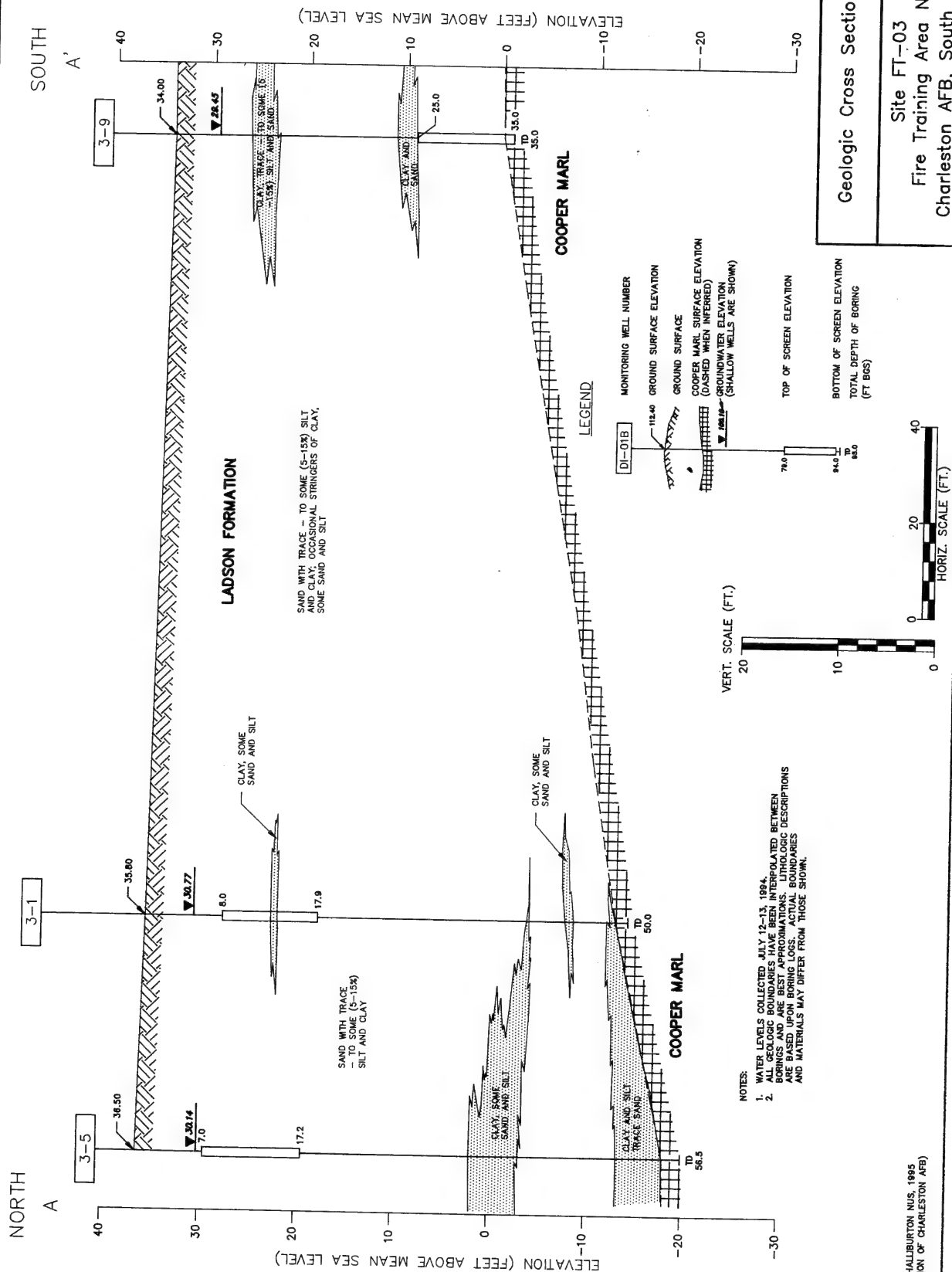
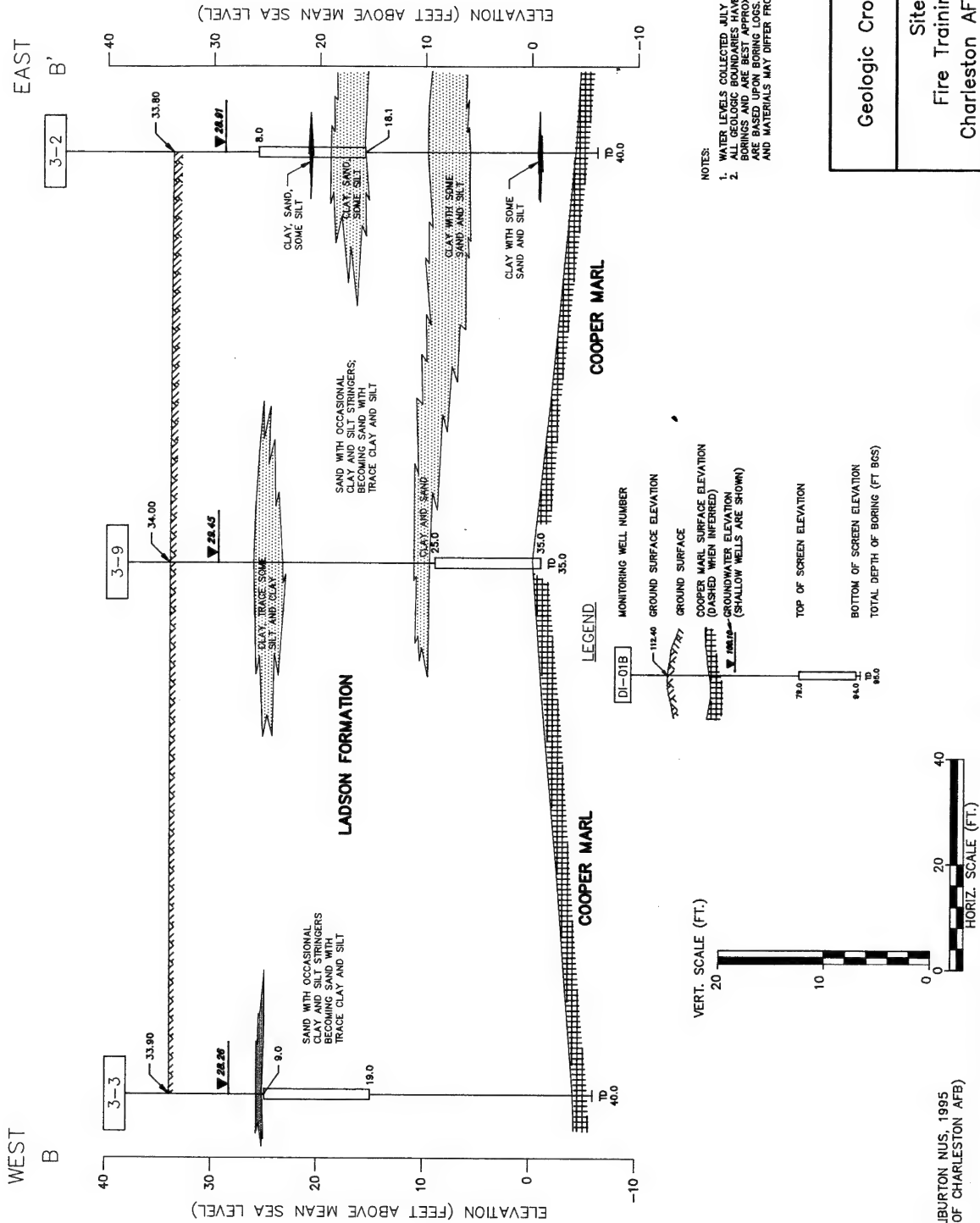


Figure 2.3



MAP AND DATA SOURCE: HALLIBURTON NUS, 1995
(REPRODUCED BY PERMISSION OF CHARLESTON AFB)

Figure 2.4



MAP AND DATA SOURCE: HALLIBURTON MUS. 1995
(REPRODUCED BY PERMISSION OF CHARLESTON AFB)

Geologic Cross Section B-B'

Site FT-03
Fire Training Area No. 3
Charleston AFB, South Carolina

The predominant direction of shallow groundwater flow is to the south and southeast toward a tributary of Filbin Creek. Potentiometric maps provided in previous site reports indicated little seasonal variation with respect to groundwater flow direction (Versar, 1992; Halliburton, 1995). An average groundwater gradient of approximately 0.015 ft/ft was reported. Halliburton NUS performed two aquifer pump tests at the site and monitored the drawdown responses at eight monitoring wells. An average aquifer transmissivity value of 809 ft²/day was calculated using results from both tests. Aquifer storativity ranged from 0.016 to 0.00006, with an average value of 0.0006. An average hydraulic conductivity of 21 feet/day was calculated, based on an aquifer thickness of 38 feet. Based on these data and an estimated effective porosity of 0.30, the average linear groundwater flow velocity in the vicinity of Site FT-03 is 1.1 feet/day, or 380 feet/year (Halliburton NUS, 1995).

2.4 SITE CONTAMINANTS

The primary contaminants at this site are petroleum hydrocarbons, which were detected in the soils and groundwater at depths ranging from ground surface to about 30 feet bgs. TRPH maximum concentrations of 7,770 milligrams per kilogram (mg/kg) have been detected in the soils at a depth of 2 to 3 feet on the north end of the berm. Soil headspace VOCs were also detected in concentrations of 22,107 parts per billion (ppb) at this sampling point. Shallow sediment samples showed TRPH concentrations of 3,310 mg/kg during the earlier RI/FS investigations (Versar, 1992). Volatile organic compounds (VOCs) benzene, toluene, ethylbenzene, xylenes and several semi-volatile organic compounds (SVOCs) were detected in both soils and groundwater at the site. Chlorinated solvents have also been detected in soils and groundwater at low concentrations. Lead (dissolved and total) was also detected in groundwater and soils at the site (Halliburton NUS, 1995).

Initial soil sampling conducted by Engineering-Science prior to the one-year bioventing pilot test showed TRPH concentrations up to 2,200 mg/kg within shallow soils in the burn pit. Benzene was not detected in any of the soil samples collected but the compounds toluene, ethylbenzene, and total xylenes were detected in two of the three samples. Total volatile hydrocarbons (TVH) in soil gas ranged from 27 parts per million by volume (ppmv) to 790 ppmv. Ethylbenzene and xylenes also were detected at very low concentrations in soil gas samples (Engineering-Science, 1993).

During the 1992 RFI at Site FT-03, Halliburton NUS collected ten surface soil samples (<2 feet deep). Samples were analyzed for a combination of the following: volatiles, semivolatiles, TRPH, pesticides, polychlorinated biphenyls (PCBs), and inorganic constituents. Minimal SVOCs were detected in the surface soils. One sample contained elevated concentrations of lead (79.5 mg/kg) and chromium (241 mg/kg).

Seven subsurface soil samples (>2 feet deep) also were collected during the 1992 investigation. Samples were analyzed for a combination of VOCs, SVOCs, TRPH, pesticides, PCB, and inorganics constituents. BTEX and other VOC concentrations were generally low. The highest reported concentrations were 0.005 mg/kg (benzene), 0.004 mg/kg (ethylbenzene), 0.013 mg/kg (total xylenes), 0.012 mg/kg (methylene

chloride), 0.014 mg/kg (tetrachloroethene), and 0.004 mg/kg (trichloroethene). The highest reported chromium and lead concentrations in subsurface soil were 19.3 mg/kg and 52.2 mg/kg, respectively.

Six groundwater samples were collected during the 1992 investigation and seven groundwater samples were collected during a subsequent 1994 sampling event. Samples were analyzed for a combination of VOCs, SVOCs, TPH, pesticides, PCB, metals and inorganics constituents. Concentrations of BTEX and other fuel-related VOCs were generally low or not detected in most wells. The highest detected VOC concentrations were 250 micrograms per liter ($\mu\text{g/L}$) benzene, 5 $\mu\text{g/L}$ ethylbenzene, 10 $\mu\text{g/L}$ vinyl chloride, 31 $\mu\text{g/L}$ 1,2-dichloroethane, and 1 $\mu\text{g/L}$ trans-1,2-dichloroethene. The highest reported total chromium and lead concentrations in groundwater were 0.432 milligrams per liter (mg/L) and 0.915 mg/L, respectively. A more detailed discussion of the site contaminants can be found in the *Draft RCRA Facility Investigation Report, Charleston AFB, South Carolina* (Halliburton NUS, 1995).

As part of the RFI, Halliburton NUS conducted a baseline human health risk assessment for Site FT-03 in its current condition. The highest concentrations of chemicals detected in each medium at the site were compared to the base background results and to applicable or relevant and appropriate regulations (ARARs) or to be considered (TBC) action levels established as RCRA Subpart S Action Levels for the base. A list of chemicals of concern (COCs) was developed for each medium and the quantitative risk assessment was performed for each of the COCs. For soils, only chromium exceeded both background levels and ARAR/TBC levels and it was retained as a COC for further risk evaluation. A number of potential COCs were identified from the sediment sampling results and several pesticides exceeded base background and ARAR/TBC action levels. For groundwater, benzene and 1,2-dichloroethane were the only VOCs identified as COCs. Ten inorganic compounds exceeded base background and ARAR/TBC levels for groundwater and, of this total, seven metals were identified as COCs. Although it has been detected at this site, lead was not identified as a COC in any of the media. This site does not have an established ARAR/TBC, risk based concentration (RBC), or risk based corrective action (RBCA) regulatory cleanup standard for TRPH in soil.

SECTION 3

BIOVENTING PILOT TEST RESULTS

A one-year pilot test was conducted at Site FT-03 from November 1992 through November 1993 to determine if *in situ* bioventing would be a feasible cleanup technology for the fuel-contaminated soils within the unsaturated zone. The objectives of the initial bioventing pilot test were to:

- Assess the potential for supplying oxygen throughout the contaminated soil profile;
- To determine the rate at which indigenous microorganisms will degrade petroleum hydrocarbons when stimulated by oxygen-rich soil gas at this site; and
- To evaluate the potential for sustaining these rates of biodegradation until hydrocarbon contamination is remediated below regulatory-approved standards.

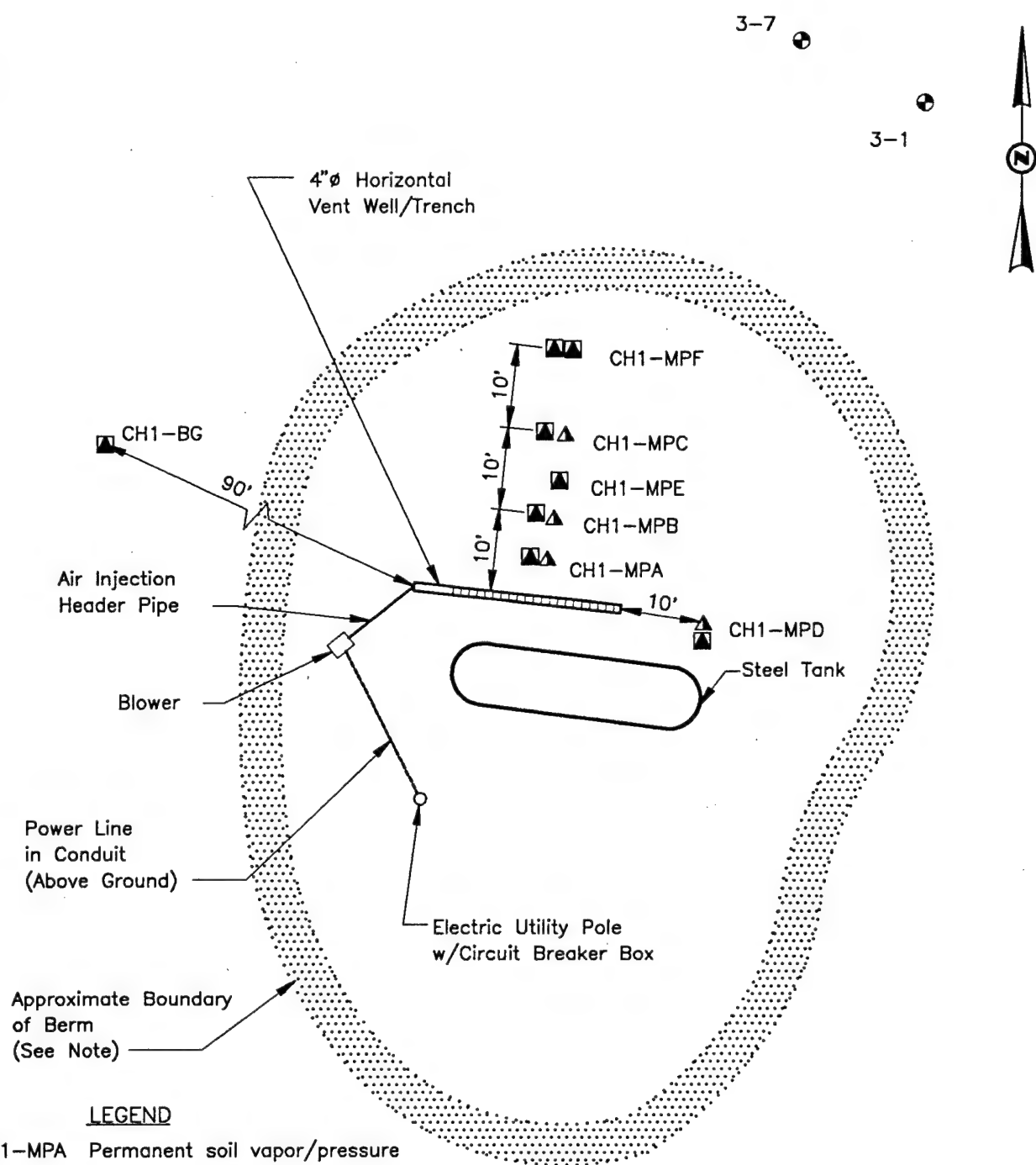
Due to the successful results of the one-year pilot test, the bioventing system has continued operation from November 1993 to the present to evaluate the effects of long-term bioventing at the site. Because bioventing has been demonstrated to be a feasible technology to remediate hydrocarbon-contaminated soils at Site FT-03, the pilot test data were used to design a full-scale remediation system to remediate additional areas at the site (see Section 4). Installation of a second horizontal vent well will remediate a larger area of soils and facilitate risk reduction for organic hydrocarbons in soils. Reduction of organic fuel contaminants in soil is expected to facilitate groundwater remediation indirectly by removing the contaminant source.

3.1 INITIAL PILOT TEST CONFIGURATION

A horizontal air injection vent well (VW) was installed on October 28, 1992 under the direction of Parsons Engineering Science, Inc. (formerly Engineering-Science, Inc.). Four permanent pressure/vapor monitoring points (VMPs) were also installed on October 29, 1992. The following sections describe in more detail the design, installation, and testing of the bioventing pilot test system used at Site FT-03.

One horizontal vent well, four permanent VMPs, and a blower unit in a weather-proof enclosure were installed at Site FT-03 for the extended bioventing test. Prior to conducting air permeability and respiration tests, shallow soil gas probes were installed adjacent to the permanent VMPs to serve as temporary VMPs. The temporary soil gas probes were installed to monitor soil gas conditions in very shallow soils (<2.5 feet deep), as an unseasonably high water table during the initial testing prevented utilization of the permanent VMPs. The unusually high water table at the site also prevented using existing groundwater monitoring wells for soil gas and pressure monitoring during the tests. A temporary soil gas probe was subsequently installed to serve as a background monitoring point. Figure 3.1 depicts the pilot test area with the

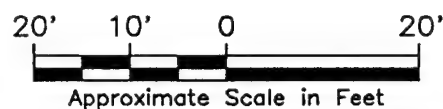
Figure 3.1



LEGEND

- CH1-MPA Permanent soil vapor/pressure monitoring point.
- CH1-MPA Temporary soil vapor/pressure monitoring point (soil gas probe).
- CH1-BG Temporary background monitoring point.
- 3-7 Groundwater monitoring well.

NOTE: Soil berm has approximate elliptical dimensions and varying widths. Locations of tank, vent well, and utility pole within berm are estimated.



Bioventing Pilot Test Installations

Site FT-03
Fire Training Area No. 3
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locations of the permanent and temporary VMPs, the horizontal VW, and the air injection blower.

3.1.1 Air Injection Vent Well

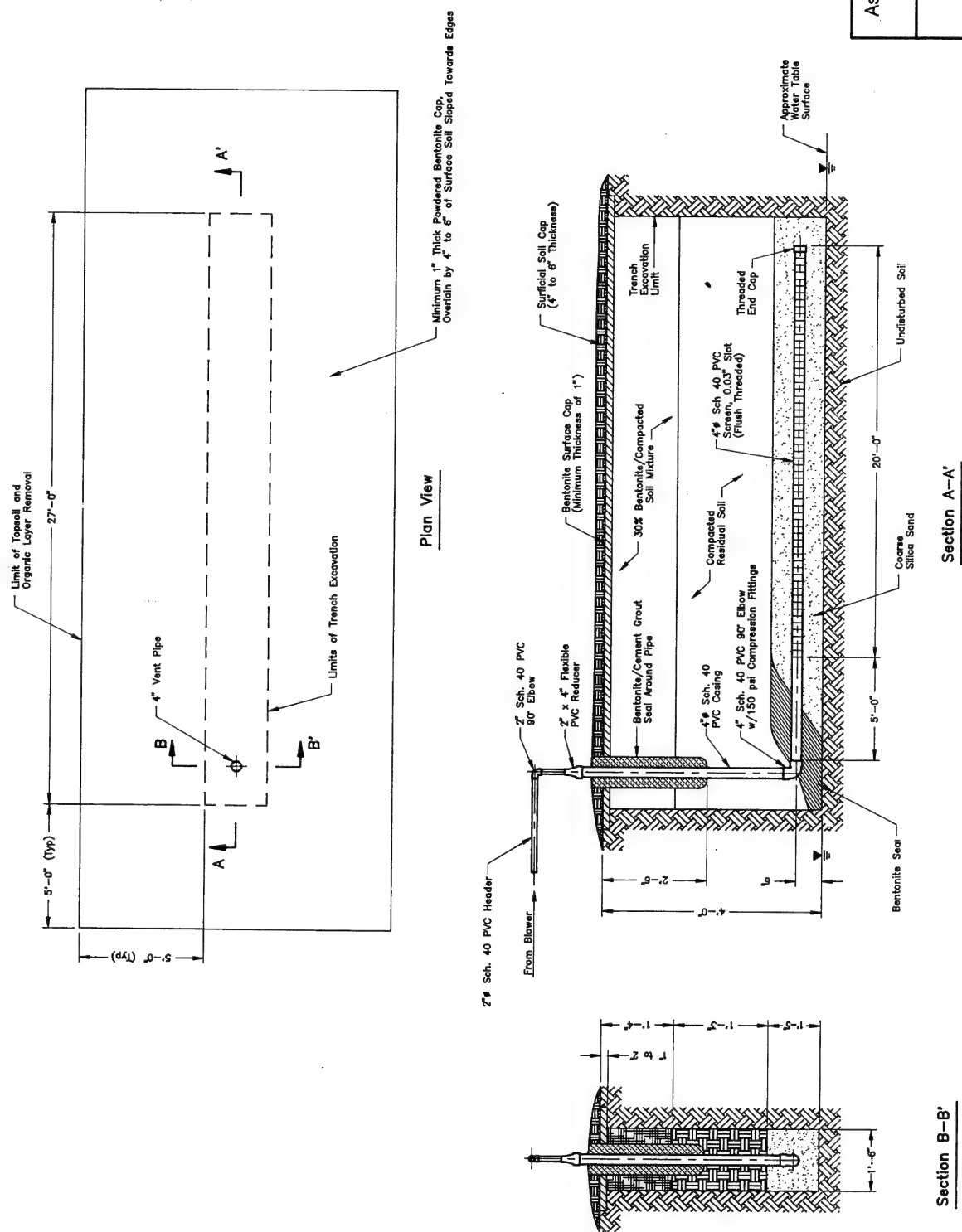
The air injection vent well was installed within the bermed area on the north side of the fire training pit as shown in Figure 3.1. The vent well was constructed in a shallow trench excavated in visibly contaminated, oxygen-depleted soils. Soils in the immediate vicinity of the trench were dark stained and contained strong hydrocarbon odors. A horizontal air injection vent well was installed at this site because the relatively shallow water table and limited vadose zone prevented the installation of a vertical vent well. Figure 3.2 shows the as-built construction details of the trench and vent well. On the date of the vent well/trench installation, water levels at Site FT-03 were approximately 4 feet bgs. Water level elevations observed during the pilot test were 1 to 2 feet higher than the historical normal water levels for that time of year as reported in previous IRP reports for this site (Versar, 1992). Consequently, the bottom of the horizontal vent well was installed at approximately 3.5 feet bgs to avoid the high water table conditions that existed in the burn pit. As-built construction and operating details for the horizontal air injection vent well are provided in the *Draft Interim Bioventing Pilot Test Results Report for Fire Protection Training Area Site FT-03, Charleston AFB, South Carolina* (Engineering-Science, 1993).

3.1.2 Permanent Monitoring Points

Four permanent VMPs were installed on October 29, 1992. Monitoring points MPA, MPB, MPC were installed perpendicular to the vent well axis at respective distances of 5, 10 and 20 feet, while the fourth point (MPD) was installed parallel to the vent well axis 10 feet from the east end of the vent well (see Figure 3.1). The permanent VMP boreholes were advanced using a decontaminated hand auger. Only one VMP screen was installed per borehole. Multi-depth VMP screens could not be installed at Site FT-03, as the shallow water table conditions would not accommodate construction of multiple bentonite and grout seals with adequate integrity.

The four permanent monitoring points were constructed using 0.5-inch diameter PVC screens and casings installed in a 4-inch diameter borehole. Each VMP was constructed using a 6-inch section of 0.02-inch slot, schedule 80 PVC screen and schedule 40 PVC casing. The screened interval was surrounded by a gravel pack of #2 coarse silica sand. Thermocouples also were installed to measure soil temperature at the screened interval of monitoring points MPD-3.9 and MPA-3.5. Bentonite and grout seals were used to seal the annulus around the riser above the gravel pack. The top of each PVC riser was completed near the ground surface with a brass gas ball valve and a 3/16-inch hose barb. Each VMP was completed at the surface with a flush-mount metal well vault set in a concrete base. The lid of the metal well vault was set several inches above the ground surface, and the concrete base was sloped toward the edges to promote drainage of surface water away from the VMP. Figure 3.3 shows a typical construction schematic for the permanent VMPs at this site. Construction details listing the depths and screened intervals of each permanent VMP also are shown in Figure 3.3.

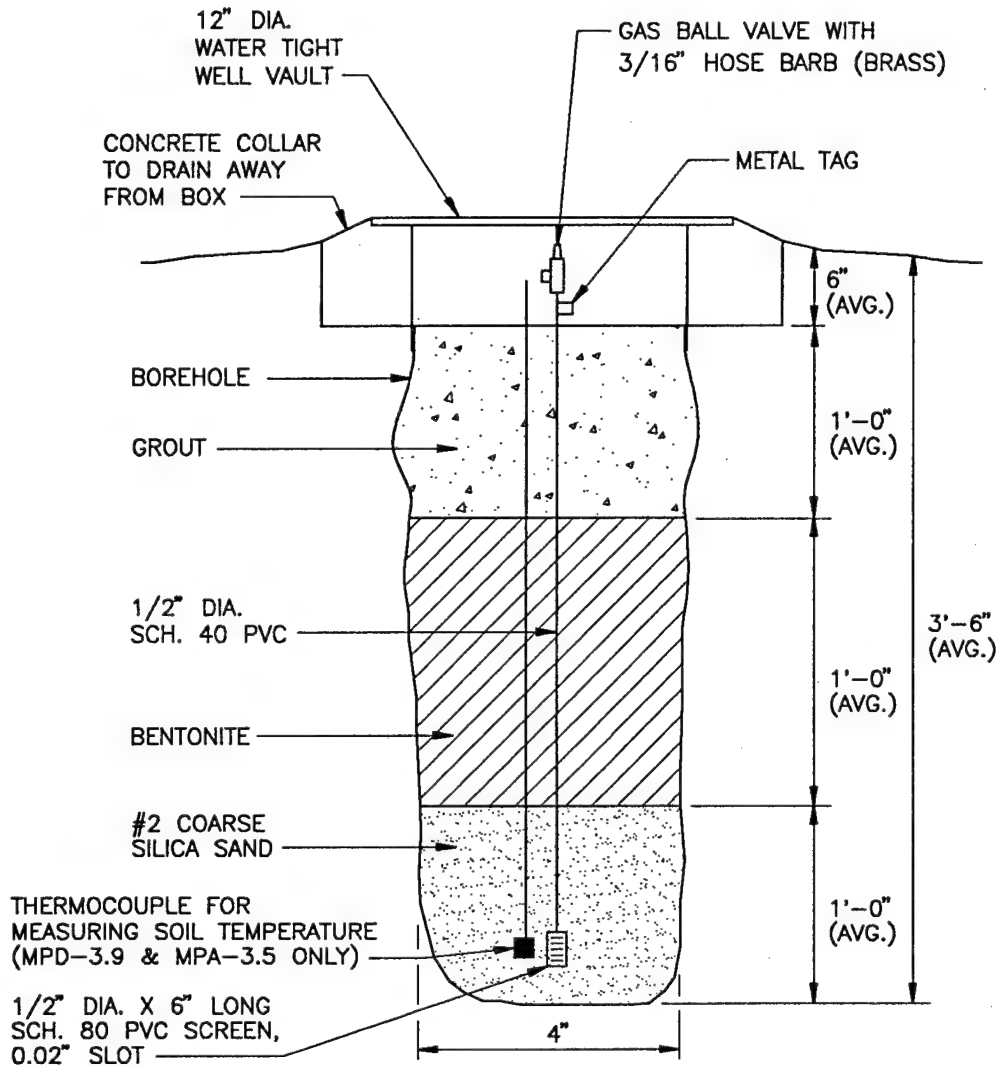
Figure 3.2



As-Built Schematic of Pilot Test
Vent Well

Site FT-03
Fire Training Area No. 3
Charleston AFB, South Carolina

Figure 3.3



DRAWING IS NOT TO SCALE

MONITORING POINT CONSTRUCTION SPECIFICATIONS

Monitoring Point No.	Borehole Depth (FT)	Screen Interval (Feet BLS)
MPA-3.5	3.5	2.5-3.0
MPB-3.5	3.5	2.5-3.0
MPC-3.25	3.25	2.6-3.1
MPD-3.9	3.9	2.8-3.3

As-Built Schematic of Permanent Vapor Monitoring Point

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Charleston AFB, South Carolina

3.1.3 Temporary Monitoring Points

Eight temporary VMPs were installed in the Site FT-03 pilot test area to monitor shallow soil gas conditions during the tests (Figure 3.1). Five of the points, including the background monitoring point CH1-BG, were installed on November 9, 1992 prior to conducting the air permeability test. Three additional temporary VMPs (MPE and MPF) were installed after evaluating the air permeability test responses and before conducting the in-situ respiration test. One of the temporary monitoring points (MPE) was used to replace MPA-3.5, which began collecting water in the screens after prolonged heavy rains elevated the water table even further at the site.

The temporary VMPs were installed using an AMS Soil Gas Vapor Kit and dedicated soil vapor probes. The soil vapor probes were advanced adjacent to existing permanent VMPs to provide the shallow monitoring intervals (i.e. 1 to 2 feet deep) that could not be constructed in the boreholes using PVC screens and riser. With the exception of the background VMP, most of the soil vapor probes did not exceed a depth of 2.5 feet. Each temporary monitoring point was advanced to the desired depth using a carbon steel rod with internal polypropylene tubing connected to the soil vapor probe. Soil around the steel rod was tamped to prevent short-circuiting of air between the probe tip and the ground surface. Care was also used not to purge large volumes of air through the probes so that ambient atmospheric air was not retrieved during soil gas monitoring procedures. The temporary soil gas monitoring probes were removed at the end of the one-year pilot test.

3.1.4 Blower Unit Installation and Operation

A 1-horsepower Gast R4110-2 regenerative blower unit was installed at Site FT-03 for the extended pilot test. The air permeability test was conducted using a portable 1-horsepower Rotron DR404 regenerative blower. The Gast blower was installed in a weatherproof enclosure and is energized by a 230-volt, single-phase, 30-amp circuit from a nearby above-ground, electrical utility pole and circuit breaker box provided by the base. Air is supplied by the blower through a 2-inch diameter above ground PVC header pipe that is attached to the vent well using a flexible PVC 4"x2" reducer.

The blower began operation for the extended bioventing test on November 23, 1992. Before starting the extended test, water was noted in the vent well as a result of four consecutive days of heavy rainfall the prior week. A water level was measured in the vent well and it was determined that the horizontal VW piping was submerged under approximately 11 inches of water. The elevated water table at the site was confirmed by placing a hand-augered boring on the north edge of the fire pit berm, where the water table stabilized in the open borehole at a depth of 2.2 feet bgs.

Rather than wait for the water levels to subside at the site, the extended bioventing test began by first starting the blower with the manual pressure relief valve fully open and then slowly closing the valve to begin blowing pressurized air into the vent well at an initial injection pressure of 42 inches of water and an air flow rate of approximately 45 standard cubic feet per minute (scfm). The initial high injection pressure was intended to remove the water from the vent well and surrounding formation so that effective air flow could be established in the unsaturated zone until the water levels

subsided. The air flow and injection pressures into the VW have since been reduced significantly by opening the manual pressure relief valve even further to bypass a large portion of the air to the atmosphere. The long-term operating air injection rate has varied from approximately 15 to 20 scfm at 12 to 26 inches of water pressure at the horizontal VW. Injection pressures vary based on soil moisture and water table influences on the horizontal well. Measurable soil pore pressures are being maintained at distances up to 30 feet under these operating conditions.

3.2 PILOT TEST PROCEDURES AND RESULTS

During installation of the VW and VMPs, soil samples were collected for laboratory analyses to establish baseline TRPH and BTEX concentrations and various inorganic and physical parameters. Results of these baseline soil analyses are summarized in Table 3.1 and Table 3.2. Soil gas samples were also collected for laboratory analyses from two VMPs to establish soil gas TVH and BTEX concentrations. The soil gas results are also summarized in Table 3.2.

Prior to initiating air injection, all VMPs were purged until oxygen levels had stabilized, and baseline oxygen, carbon dioxide, and then TVH concentrations were sampled using portable gas analyzers, as described in the technical protocol document (Hinchee et al., 1992). In contaminated soils, microorganisms had depleted soil gas oxygen concentrations to less than 1 percent. In contrast, the background VMP, outside the area of contamination, had 20.8 percent oxygen at a depth of 2.5 feet.

3.2.1 Baseline and Final Soil Hydrocarbon Concentrations

As described in previous investigations, soil hydrocarbon contamination at Site FT-03 appears to be confined mainly around the former burn pit within the bermed area. During the bioventing pilot test installations, contaminated soils were identified based on visual appearance, odor, and VOC field screening results. Heavily contaminated soils were encountered in the vent well trench and MPD borehole during initial system installation. Soils in these areas had strong hydrocarbon odors and were visibly stained from oily fuel contamination. Groundwater encountered during the trench excavation did not contain immiscible, floating fuel product.

During VW and VMP construction in November 1992, the greatest concentrations of soil contamination appeared to occur in the upper three feet of the soil profile. Soil samples for laboratory analysis were collected using a hand auger. Soil samples collected from the monitoring point borings were placed in air-tight plastic bags and screened for VOCs using a photoionization detector (PID). The PID headspace screening results were used to determine the relative contamination of each sample and as a guide for selecting samples for laboratory analyses. Soil samples for laboratory analysis were collected from MPA at a depth of 2.5 feet, from MPD at a depth of 3 feet, and from the VW trench at a depth of 3.5 feet. Each of the soil samples were analyzed for the following parameters: TRPH; individual BTEX compounds; iron; alkalinity; total Kjeldahl nitrogen (TKN); pH; phosphates; percent moisture; and grain size distribution. The results of these baseline analyses are presented in Table 3.1.

TABLE 3.1

**INITIAL SOIL SAMPLE LABORATORY ANALYTICAL RESULTS
BIOVENTING PILOT TEST
SITE FT-03
CHARLESTON AFB, SOUTH CAROLINA**

Analyte (Units) ^{a/}		Sample Location-Depth (feet below land surface)		
<u>Soil Hydrocarbons</u>	<u>VW-3.5</u>	<u>MPA-2.5</u>	<u>MPD-3</u>	
TRPH (mg/kg)	1,100	51	2,200	
Benzene (mg/kg)	ND ^{b/}	ND	ND	
Toluene (mg/kg)	2.6	2.7	ND	
Ethylbenzene (mg/kg)	1.6	ND	ND	
Xylenes (mg/kg)	4.6	1.3	ND	
<u>Soil Inorganics</u>	<u>VW-3.5</u>	<u>MPA-2.5</u>	<u>MPD-3</u>	
Iron (mg/kg)	3,760	3,010	2,060	
Alkalinity (mg/kg as CaCO ₃)	650	ND	170	
pH (units)	7.4	6.6	7.4	
TKN (mg/kg)	180	520	360	
Phosphates (mg/kg)	96	850	100	
<u>Soil Physical Parameters</u>	<u>VW-3.5</u>	<u>MPA-2.5</u>	<u>MPD-3</u>	
Moisture (% wt.)	16.5	15.4	11.3	
Gravel (%)	0	6	0	
Sand (%)	74	65.5	75	
Silt (%)	19	21	20	
Clay (%)	7	7.5	5	

^{a/} TRPH = total recoverable petroleum hydrocarbons; mg/kg = milligrams per kilogram, ppmv = parts per million, volume per volume; CaCO₃ = calcium carbonate; TKN = total Kjeldahl nitrogen.

^{b/} ND = not detected.

TABLE 3.2
INITIAL AND 1-YEAR SOIL AND SOIL GAS ANALYTICAL RESULTS
SITE FT-03
CHARLESTON AFB, SOUTH CAROLINA

Analyte (Units) ^{a/}	Sample Location-Depth (feet below ground surface)					
	MPA-3.5		MPC-3.25		MPD-3.9	
	Initial ^{b/}	1-Year ^{c/}	Initial	1-Year	Initial	1-Year
Soil Gas Hydrocarbons						
TVH (ppmv)	27	0.47	NS ^{d/}	0.78	790	13
Benzene (ppmv)	<0.002	<0.002	NS	<0.002	<0.04	<0.002
Toluene (ppmv)	<0.002	<0.002	NS	<0.002	<0.04	<0.002
Ethylbenzene (ppmv)	<0.002	<0.002	NS	0.002	0.12	<0.002
Xylenes (ppmv)	0.002	<0.002	NS	<0.002	0.22	<0.002
Soil Hydrocarbons						
	VW-3.5		MPA-2.5		MPD-3	
	Initial ^{e/}	1-Year ^{f/}	Initial	1-Year	Initial	1-Year
TRPH (mg/kg)	1,100	170	51	12	2,200	2,200
Benzene (mg/kg)	<0.73	<0.0027	<0.72	<0.0006	<1.4	<0.54
Toluene (mg/kg)	2.6	<0.0027	2.7	<0.0006	<1.1	<0.54
Ethylbenzene (mg/kg)	1.6	<0.0027	<0.6	<0.0006	<1.6	<0.54
Xylenes (mg/kg)	4.6	<0.0038	1.3	<0.0006	<2.1	<0.75
Moisture (%)	17.9	8.5	16.8	9.1	12.6	6.6

^{a/} TRPH=total recoverable petroleum hydrocarbons; mg/kg=milligrams per kilogram;

TVH= total volatile hydrocarbons; ppmv=parts per million, volume per volume;

^{b/} Initial soil gas samples collected on May 6, 1993.

^{c/} Final soil gas samples collected on November 11, 1993.

^{d/} NS=not sampled.

^{e/} Initial soil samples collected on October 29, 1992.

^{f/} Final soil samples collected on November 11, 1993.

After completing one year of bioventing testing, confirmation soil samples were collected at the original sampling locations and analyzed for TRPH, BTEX and moisture. The purpose of the final sampling was to provide a qualitative indication of reduction in contaminant mass. A significant reduction of TRPH and BTEX compounds was observed in the soils after one year of bioventing. A comparison of the baseline and final soil sampling results from the one-year pilot test is provided in Table 3.2.

3.2.2 Baseline and Final Soil Gas Hydrocarbons

Initial and final soil gas samples were collected for laboratory analyses of TVH and BTEX compounds during the bioventing pilot test. Due to elevated water table conditions (e.g. <2.5 feet bgs), baseline laboratory soil gas samples could not be collected from the permanent VMPs prior to the pilot test startup. As a result, initial soil gas samples were not collected for laboratory analyses until May 1993, when the water table had subsided and the blower was shut down for a respiration test after six months of operation.

After one-year of bioventing, final soil gas samples were collected for laboratory analyses for TVH and BTEX compounds. These results were compared to results of soil gas samples collected after six months of operation to provide a qualitative indication of reduction in soil gas hydrocarbon mass. A significant reduction of TVH and BTEX compounds was observed in soil gas after one year of bioventing. A comparison of initial and final soil gas sampling results is also provided in Table 3.2. Initial soil gas BTEX and TVH results shown in Table 3.2 were likely influenced by the six months of blower operation and therefore do not reflect the actual baseline (pretest) conditions. Baseline soil gas hydrocarbon concentrations were likely higher than the "initial" results shown in this table.

3.2.3 Air Permeability Test

An air permeability test was conducted according to bioventing protocol and work plan procedures. Air was injected into the VW at a rate of approximately 27.5 scfm and an average pressure of approximately 50 inches of water. Air injection continued for three hours until approximate steady-state pressure conditions were achieved. The HyperVentilate® model was used to determine soil permeability based on time versus pressure responses measured at various VMPs. Soil air permeability values ranging from 4 to 8 darcys were calculated for this site. These results are reasonable for a fine sandy soil matrix. The radius of soil pressure influence measured during the air permeability test was estimated to be between 30 and 40 feet.

3.2.4 Bioventing Oxygen Influence

The depth and radius of oxygen increase in the subsurface resulting from air injection into a VW during pilot testing is the primary design parameter for full-scale bioventing systems. Optimization of full-scale and multiple VW systems requires pilot testing to determine the volume of soil that can be oxygenated at a given flow rate and VW screen configuration. Oxygen concentrations in soil gas were measured at several

times during the pilot test to determine the short-term and long-term influences of air injection on soil gas oxygen concentrations.

3.2.4.1 Short-Term Oxygen Influence

Table 3.3 summarizes the change in soil gas oxygen levels that occurred during the air permeability test when air was injected at 27.5 scfm for a period of 3 hours. Oxygen level increases were measured at all VMPs except in MPD at a depth of 1.8 feet, where the oxygen level remained constant, and in MPC at a depth of 1.5 feet, where the oxygen level decreased during the test. Short-term oxygen reduction at MPC (1.5 feet) was likely due to oxygen-depleted soil gas being transported away from the VW during air injection. No final oxygen reading was taken from MPC at the 3.25-foot depth due to high water in this VMP during the air permeability test. These changes in oxygen levels indicate air movement through the soils at distances up to 20 feet during the short-term air permeability test.

3.2.4.2 Extended Bioventing Oxygen Influence

Soil gas oxygen, carbon dioxide, and TVH levels were measured periodically during the extended bioventing pilot test to determine the operating effectiveness of the system. Generally, soil gas measurements collected during extended testing are better indicators of the long-term influence of air injection on soil gas conditions. Soil gas oxygen distribution observed during extended air injection into a single VW is the best indicator of the radius of influence of the bioventing system. These results are useful in determining full-scale design criteria.

Table 3.4 shows the results of soil gas indicators that were field measured at various times during the extended bioventing pilot test. The November 1992 field data in Table 3.4 represent the pretest (i.e. baseline) soil gas conditions prior to air injection. Baseline soil gas conditions on that date showed oxygen-depleted soil gas in all of the deeper VMPs in the test area. Additionally, baseline soil gas concentrations of carbon dioxide and TVH were elevated in the VMPs at that time.

The May 1993 field data in Table 3.4 represent soil gas conditions after six months of air injection at flow rates of about 15 scfm to 18 scfm. Data in this table show good horizontal and vertical distribution of oxygen in subsurface soils at distances up to 20 feet from the VW. All of the deeper permanent VMPs that were measured had close to 20% oxygen in soil gas after six months of operation. Temporary monitoring point MPC (1.5-foot depth) located 20 feet from the VW had 17.5% oxygen. Temporary monitoring point MPF (1.5-foot depth) located 30 feet from the VW showed no detection (0%) of oxygen in soil gas. These results suggest a very distinct limit to the zones of shallow soil oxygenation that ended somewhere between 20 and 30 feet from the VW.

The June 1996 data in Table 3.4, representative of 3.5 years of air injection, is similar to the May 1993 soil gas data. Soil gas measured in permanent VMPs in June 1996 all showed greater than 20% oxygen in soil gas. Additionally, the results of the expanded soil gas survey conducted by Parsons ES (see Section 3.3) are presented in this table. These soil gas conditions also confirm that the long-term effective radius of oxygen influence is between 25 to 30 feet.

TABLE 3.3

INFLUENCE OF SHORT-TERM AIR INJECTION AT VENTING
WELL ON MONITORING POINT OXYGEN LEVELS
SITE FT-03
CHARLESTON AFB, SOUTH CAROLINA

Air Permeability Test Results

MP	Distance From VW (ft)	Depth (ft)	Initial O ₂ (%)	Final O ₂ (%) ^{a/}
A	5	1.4	9.9	17.6
B	10	1.5	6.0	11.5
C	20	1.5	12.2	3.3
D	10	1.8	0.8	0.8
A	5	3.5	0.0	13.2
B	10	3.5	0.0	0.2
C	20	3.25	0.0	-- ^{b/}
D	10	3.9	0.0	13.7

^{a/} Reading taken at end of 3-hour air permeability test.

^{b/} No reading due to water in MP.

TABLE 3.4
SOIL GAS SCREENING INDICATORS
SITE FT-03
CHARLESTON AFB, SOUTH CAROLINA

November 1992: Baseline Conditions

Sample Location	Depth (ft)	Distance from VW (ft)	O ₂ (%)	CO ₂ (%)	TVH (ppmv) ^{a/}	Temp (°F)
MPA	1.4	5	9.9	4.0	2,800	NS ^{b/}
MPB	1.5	10	6	6.2	1,860	NS
MPC	1.5	20	12.2	4.3	110	NS
MPD	1.8	10	0.8	7.3	5,600	NS
MPA	3.5	5	0	8.2	5,000	63.8
MPB	3.5	10	0	7.8	1,400	NS
MPC	3.25	20	0	6.3	200	NS
MPD	3.9	10	0	8.4	>20,000	65.0
Background	2.5	90	18.7	0.2	94	NS

May 1993: 6 Months of Operation

Sample Location	Depth (ft)	Distance from VW (ft)	O ₂ (%)	CO ₂ (%)	TVH (ppmv) ^{a/}	Temp (°F)
MPA	3.5	5	20.5	0.4	7	67.4
MPB	3.5	10	20.5	0.5	7	NS
MPC	1.5	20	17.5	3.5	34	NS
MPD	1.8	10	16.0	3.8	950	NS
MPD	3.9	10	19.7	0.9	130	66.8
MPF	1.5	30	0	13	72	NS

June 1996: 3.5 Years of Operation

Sample Location	Depth (ft)	Distance from VW (ft)	O ₂ (%)	CO ₂ (%)	TVH (ppmv) ^{a/}	Temp (°F)
MPB	3.5	10	20.8	0.5	20	NS
MPC	3.25	20	20.7	0.7	26	NS
MPD	3.9	10	20.8	0.8	14	NS
SG96-1	3	17	19.8	1.6	26	NS
SG96-2	3	27	5.5	9.8	74	NS
SG96-3	3	51	0.5	11.8	320	NS
SG96-4	3	31	6.0	8.8	140	NS
SG96-5	3	25	20.0	0.6	12	NS
SG96-6	3	48	5.2	7.5	100	NS
SG96-7	3	69	0.9	10.0	1,000	NS
SG96-8	3	60	2.7	9.2	900	NS

^{a/} Hydrocarbon meter field screening results (Total Volatile Hydrocarbons).

^{b/} NS = not sampled.

Notes: 1) Blower was injecting air at rates of 15 to 18 scfm during May 1993 and June 1996 monitoring events.

2) See Figure 3.4 for locations of SG96-1 through SG96-8.

3.2.5 In-Situ Respiration Rates

In situ respiration testing was conducted to determine the biodegradation rates of indigenous bacteria in contaminated subsurface soils. Table 3.5 shows the results of three *in situ* respiration testing events conducted as part of the bioventing pilot test. These testing events are listed as the initial, 6-month, and 12-month respiration tests.

The initial *in situ* respiration tests were conducted before turning on the air injection blower for pilot-scale operation. These initial tests were performed by injecting ambient air (21% oxygen) into the VMP screened intervals for a 12.5-hour period. Only two permanent monitoring points were useable for the initial tests due to the presence of water in the VMPs, which submerged the vapor probes. Small 1 scfm air pumps were used for air injection during the initial respiration tests. Changes in soil gas composition over time were measured after the air injection ceased. Oxygen, TVH, and carbon dioxide were measured for 30 hours following air injection. Air injection into the VW during the one-year pilot study oxygenated soils within the test area. As a result, the 6-month and 1-year respiration tests were performed by turning off the blower system and monitoring oxygen, carbon dioxide, and TVH levels in the VMPs.

The fuel biodegradation results determined by *in situ* respiration testing at this site are presented in Table 3.5 for the three testing events. Fuel biodegradation rates decreased slightly in most of the VMPs between the 6-month and 1-year respiration tests. Results from the respiration tests indicate that the hydrocarbon-contaminated soils have active microorganism populations and that biological respiration was still occurring in the soils after one year of air injection. The biodegradation rates presented in Table 3.5 are based on calculated air-filled porosities (liters of air per kilogram of soil) and a ratio of 3.5 milligrams of oxygen consumed for every 1 milligram of fuel biodegraded.

The background soil gas oxygen concentration for Site FT-03 was 18.7% as measured at a temporary soil gas monitoring point placed in shallow, uncontaminated soils. Air was also injected into this point to conduct a respiration test. There appeared to be little oxygen uptake due to abiotic reactions or non-fuel biodegradation. The percent oxygen measured at the background VMP remained essentially constant at 20 percent throughout the respiration test. Therefore, it can be assumed that oxygen uptake observed at this site is primarily the result of microbial biodegradation of fuel hydrocarbons.

3.3 EXTENDED SOIL GAS SURVEY

On June 12, 1996, Parsons ES conducted an additional soil gas survey at the site. The objectives of the survey were 1) to evaluate the long-term effectiveness of the existing vent well and blower system to oxygenate the soils, 2) to identify areas of the burn pit that still have oxygen-depleted soil gas and hydrocarbon contamination and 3) to assess the need and potential location for an additional vent well(s) at the site. Soil gas samples were collected while the existing VW was still operating. On the north side of the burn pit, soil gas samples and soil pressures were collected from three existing permanent VMPs (MPB-3.5, MPC-3.25, and MPD-3.9). On the south side of

TABLE 3.5
RESPIRATION AND FUEL BIODEGRADATION RATES
SITE FT-03
CHARLESTON AFB, SOUTH CAROLINA

Location-Depth (feet below ground surface)	Initial (November 1992)			6-Month (May 1993)			1-Year (November 1993)		
	K _o (% O ₂ /min)	Degradation Rate (mg/kg/year) ^{a/}	Soil Temperature (°C)	K _o (% O ₂ /min)	Degradation Rate ^{b/} (mg/kg/year)	Soil Temperature (°C)	K _o (% O ₂ /min)	Degradation Rate (mg/kg/year)	Soil Temperature (°C)
MPA-3.5	NA ^{a/}	NA	NA	0.0046	270	19.7	0.00085	120	16.9
MPB-3.5	NA	NA	NA	0.0018	110	NS ^{d/}	0.00045	60	NS
MPC-3.25	NA	NA	NA	NS	NS	NS	0.00036	70	NS
MPD-1.8	NA	NA	NA	0.0031	370	NS	0.0028	510	NS
MPD-3.9	0.0088	580	19.0	0.014	1,690	19.3	0.0025	450	17.3

^{a/} Milligrams hydrocarbons per kilogram soil per year.

^{b/} Assumes moisture content of the soil is average of initial and final moistures.

^{c/} NA=Not available; monitoring point was submerged during initial testing.

^{d/} NS=Not sampled.

the burn pit, eight temporary soil gas probes were installed using a soil gas kit with retractable, screened sampling probes. Oxygen, carbon dioxide and TVH soil gas concentrations were measured at each point as indicators of bioventing progress. Results of the soil gas survey are listed under the June 1996 sampling event in Table 3.4. Figure 3.4 graphically depicts the soil gas results.

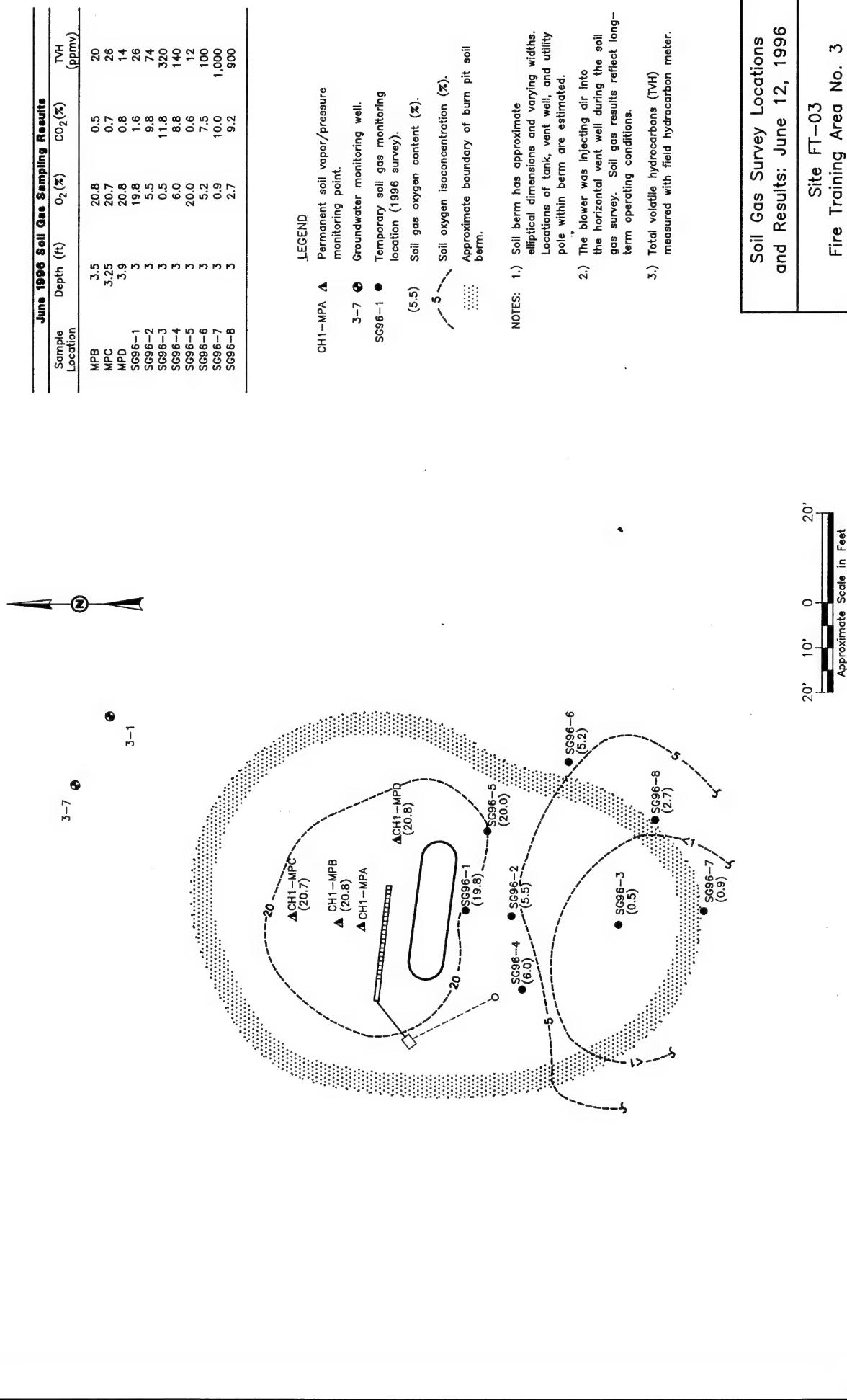
A comparison of the November 1992 data (baseline conditions) to the June 1996 data (3.5 years of operation) in Table 3.4 indicates the effectiveness of the existing bioventing system to reduce TVH concentrations in the soil gas, while aerating formerly oxygen-depleted soils. In monitoring point MPB-3.5, TVH soil gas concentrations were reduced from an initial level of 1,400 ppmv to 20 ppmv in June 1996. TVH concentrations in MPD-3.9 were reduced from >20,000 ppmv to 14 ppmv. Substantial TVH reductions were also observed in monitoring point MPC-3.25. Soil gas oxygen levels were initially 0% in monitoring points MPB-3.5, MPC-3.25, and MPD-3.9. These oxygen concentrations had increased to greater than 20% during June 1996.

Eight additional temporary soil gas monitoring points (SG96-1 through SG96-8) were installed on the south of the burn pit and the existing vent well. Figure 3.4 shows the locations of the temporary soil gas points and the soil gas results, including the approximate distribution of soil gas oxygen content at the 3-foot depth. Elevated TVH concentrations were observed at points SG96-3, SG96-4, SG96-7, and SG96-8, suggesting that fuel hydrocarbons still exist in the subsurface on the south side of the burn pit. Soil contamination in this area likely results from the former fire training exercises in the burn pit and possible movement of fuel-contaminated groundwater toward the south. Soil gas oxygen and carbon dioxide concentrations were also measured at the temporary soil gas monitoring points. Reduced soil gas oxygen levels in subsurface soils were observed in soil gas points SG96-3 (0.5%), SG96-4 (6.0%), SG96-6 (5.2%), SG96-7 (0.9%), and SG96-8 (2.7%). Elevated carbon dioxide levels were also observed at most of these locations, indicative of microbial respiration (see Table 3.4).

These data indicate that the existing bioventing system is oxygenating subsurface soils within an approximate 25-foot to 30-foot radius of the horizontal VW. There was a distinct reduction of soil gas oxygen concentrations from SG96-1 (19.8% oxygen), at a radius of 17 feet from the VW, compared to results from SG96-2 (5.5 % oxygen) at a radius of 27 feet from the VW. As indicated by the oxygen isoconcentration contours shown in Figure 3.4, there is a significant area of oxygen-depleted soils on the south end of the burn pit that is not being affected by air injection from the existing bioventing system.

Previous respiration testing demonstrated that aerobic biodegradation of fuel hydrocarbons can be stimulated under these oxygen-enhanced conditions. It appears that residual soil contamination still exists within the site, especially on the south end of the burn pit. Additional sampling will be required to determine the actual distribution and concentrations of hydrocarbons that are currently present in soil.

Figure 3.4



Soil Gas Survey Locations
and Results: June 12, 1996

Site FT-03
Fire Training Area No. 3
Charleston AFB, South Carolina

3.4 POTENTIAL AIR EMISSIONS

Emissions of fugitive vapors from the soil to the atmosphere are not an operating concern for the proposed system. Ambient air was monitored in the breathing zone during the pilot system startup and no hydrocarbons were detected at sustained concentrations above 5 ppmv. Subsequent air monitoring later in the pilot test showed no detection of hydrocarbon vapors in atmospheric air around the test zone.

During the November 1992 pilot test soil sampling event, Parsons ES determined that soil BTEX concentrations initially ranged from below detection limits to 8.8 mg/kg. No benzene was detected in the soil or soil gas analyses (Table 3.2). The average operating air injection flow rate for the pilot-scale bioventing system is low, ranging from approximately 15 to 20 scfm. Monitoring data suggest that the TVH soil gas concentrations have decreased due to the air injection and biodegradation processes. Minor losses of soil vapors to the atmosphere was expected during startup of the pilot test system due to the shallow nature of the site contaminants. Similar conditions should be expected during startup of the expanded system. However, the low air injection rates, combined with minimal BTEX concentrations detected in site soils and soil gas, should minimize fugitive emissions that potentially may occur during startup.

3.5 RECOMMENDATION FOR FULL-SCALE BIOVENTING

Based on the positive results of the one-year bioventing pilot test and continued operation of that system for an additional 2.5 years, AFCEE has provided funding for the design and installation of an expanded bioventing system that will remediate the remaining fuel-contaminated soils at Site FT-03. AFCEE has retained Parsons ES to continue bioventing services at Charleston AFB and to complete the design and installation of an expanded bioventing system. Based on the initial pilot test results, available analytical data, and recently completed soil gas sampling, Parsons ES has prepared a conceptual full-scale upgrade design that will employ the existing horizontal VW and an additional horizontal VW located on the south side of the burn pit. Six additional VMPs also will be installed to ensure oxygen is being delivered to contaminated soils. In addition, five more soil samples will be collected to further define the extent of contamination. If field screening determines that significant soil contamination is present in these boreholes, additional VMPs may be required. Section 4 provides details on the design, construction, and operation of the expanded system. A design package has been prepared for construction of the system and is included in Appendix A of this Corrective Action Plan.

SECTION 4

EXPANDED BIOVENTING SYSTEM

The purpose of the expanded bioventing system is to provide oxygen to stimulate aerobic biodegradation of the remaining hydrocarbon contaminants present in soil at Site FT-03. Operation of the existing VW and an additional air injection VW will provide atmospheric air (oxygen) to oxygen-depleted, contaminated soils at the site. The full extent of soil contamination has not been defined; therefore, six additional soil borings will be installed and converted to VMPs. If significant soil contamination is observed in all six boreholes, additional VMPs may be installed and the new VW may be expanded in size to treat the larger area of soil contamination. Previous site investigations suggest that the majority of residual subsurface soil contaminants are found in close proximity to the burn pit.

A common blower will be used to provide air to both the existing and proposed horizontal VWs. The existing blower has operated almost continuously for more than three years and its remaining service life is questionable. As a result, a new air injection blower, blower enclosure and electrical wiring will be installed at the site.

The burn pit is surrounded by an earthen berm that collects rain water due to poor surface drainage. As a result, Parsons ES proposes to construct a soil crown with backfill soil over the proposed VW trench and surrounding areas to promote drainage away from new VW and the burn pit. Additionally, one or more drainage pathways will be made in the soil berm to promote surface drainage from the burn pit. A small drainage pathway currently passes through the east side of the soil berm. This existing drainage pathway does not adequately drain the burn pit and it may be excavated lower than its current elevation to facilitate surface drainage. There are no known underground utilities at the site. An existing overhead electrical service was installed during 1992 to provide electrical power to the blower. Currently, an aboveground electrical conduit connects the electrical disconnect on the pole to the blower. System design details are provided in Appendix A.

4.1 OBJECTIVES

Following its installation, the primary objectives for operating the expanded bioventing system will be to:

- Optimize the system to fully aerate unsaturated, subsurface soils in areas of the site designated for bioventing remediation;
- Reduce the existing hydrocarbon contaminant levels to below acceptable regulatory cleanup levels, ARARs or other cleanup criteria established for the site. In the absence of established regulatory cleanup goals for specific contaminants, such as TRPH, reduce the concentrations to levels that will gain regulatory approval for no further action;

- Eliminate the potential for continued hydrocarbon partitioning to groundwater, particularly the BTEX compounds, by removing the contaminant source from vadose zone soils; and
- Provide the most cost-effective soil remediation alternative for the site.

As stated earlier in this report, soil TRPH concentrations will be monitored during the bioventing remediation activities, even though there are no established TRPH soil cleanup criteria for this site. There are, however, established ARAR/TBC levels established for individual BTEX compounds and other VOCs, which will also be monitored in the soils. Two of the VOCs (benzene and 1,2-dichloroethane) exceeded the ARAR/TBC levels for groundwater. Reduction of organic compounds in the soils using the bioventing technology is expected to benefit groundwater remediation by removing the primary contaminant source.

4.2 BASIS OF DESIGN

Site investigation data, pilot test data, and experience at similar bioventing sites provide the basis of this bioventing design. The expanded bioventing system was designed to provide oxygen to areas having significant soil contamination. Shallow vadose zone soils and deeper soils in the hydrocarbon smear zone have been targeted for remediation. The extent and magnitude of soil contamination will be better defined in the burn pit area as part of this project. Therefore, the design includes installation of six or more additional soil borings and collection of five additional soil samples to further investigate soil contamination. If significant vadose zone contamination is encountered during field screening of soils from the borings, then the proposed horizontal VW trench may be modified to better affect other areas of the site. If significant vadose zone contamination is not encountered in a soil boring, either a VMP will be installed or the boring will be abandoned. A minimum of six additional VMPs are proposed for this site.

Pilot test data such as operating pressures, air injection flow rates and radius of oxygen influence were considered during design development. These data were considered in the placement of the VW and sizing of a full-scale blower system. In addition to the pilot test data from this site, experience at other sites with similar site conditions and soils was considered in design development. The significant design parameters and considerations are as follow:

- A radius of oxygen influence of 30 feet was used, resulting in placement of the new horizontal VW near the center of the burn area, perpendicular to the existing VW located on the north side of the burn pit. This area appears to be within the area of greatest vadose zone contamination (see Section 3.3).
- An air injection pressure capability up to 45 inches of water was assumed in sizing the full-scale bioventing blower, with long-term operating pressures in the range of 10 to 20 inches of water pressure during dry soil conditions. This is consistent with varying pressures observed during the extended pilot test when the water table is both elevated and low at the site.

- A combined air injection flow rate of between 40 to 60 scfm for both VWs was assumed based on experience at this and other sites.

The full-scale design will utilize a new blower in a pre-fabricated enclosure to provide air to the existing and proposed VWs. The proposed locations of the six additional VMPs were based on the following design criteria:

- to provide additional information on the extent of shallow soil hydrocarbon contamination,
- to evaluate the magnitude of contaminant reduction through soil gas sampling, and
- to provide important oxygen influence data.

The six proposed VMPs would be located within the anticipated radius of influence for the combined VW system to monitor system effectiveness throughout the project duration.

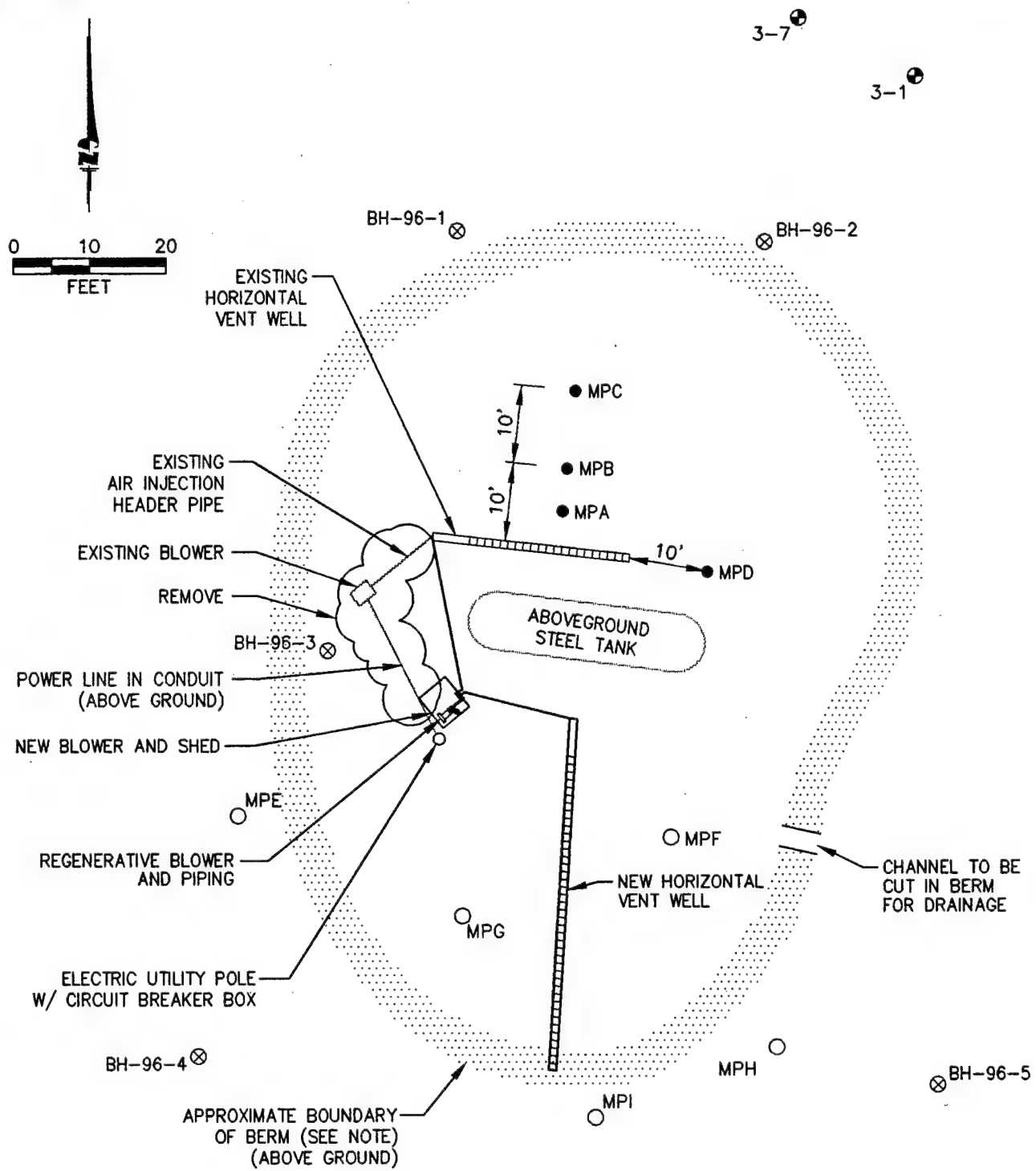
4.3 SYSTEM DESIGN

The proposed expanded bioventing system at Site FT-03 will incorporate a new regenerative blower, blower enclosure and horizontal VW. Also, a minimum of six new VMPs will be constructed to monitor soil gas conditions and to ensure adequate oxygen influence throughout the area of soil contamination. The new VW trench will be approximately 45 feet long and 3.5 feet deep. The new VW will be constructed with 4-inch diameter PVC screens and casings. The screened interval will consist of 40 feet of 0.020-inch slot recovery well screen. Figure 4.1 shows the locations of the existing and proposed new VWs and VMPs. Trench configuration and other design details are included in the design package provided in Appendix A.

The VWs will be manifolded using 2-inch-diameter, schedule 40 PVC as the conduit for the injected air to flow from the blower to the VWs. The piping will be connected to a new 1.5 HP regenerative blower and will be set at a depth of 18 inches beneath the ground surface. A separate (manual) flow control valve and flow measurement port will be included in the air injection piping connected to each VW to allow adjustment of the air flow to each VW. The blower and valving will be housed in a weatherproof enclosure for protection from the elements and for security purposes.

Based on bioventing monitoring results at this site, a maximum injection rate of 40 scfm at the new VW should be sufficient to supply oxygen to the remaining contaminated soils and sustain *in situ* fuel biodegradation. The existing pilot test VW will likely continue operating as part of the full-scale system at an air injection rate of 15 scfm or less. The effective radius of oxygen influence around the existing VW was estimated to be between 25 to 30 feet using an air injection rate of approximately 1 scfm per foot of vent well screen. Similar air flow results are expected for the proposed new VW. The proposed VW location was selected to provide coverage of contaminated, oxygen-depleted soils identified during the soil gas survey and during previous site investigations.

FIGURE 4.1



LEGEND

- 3-2 ● GROUNDWATER MONITORING WELL
- MPA ● EXISTING MONITORING POINT
- MPE ○ PROPOSED MONITORING POINT
- BH-96-1 ⊗ PROPOSED SOIL BORING

Proposed System Layout

**Site FT-03
Fire Training Area No. 3
Charleston AFB, South Carolina**

Additional soil borings will be advanced to further define the extent of soil contamination at this site. Figure 4.1 shows the proposed locations of these borings. If field screening during installation of the soil borings shows significant vadose zone contamination outside of the burn pit, then the proposed VW will be extended further south and additional VMPs will be installed in this area. Two soil borings also will be advanced north of the burn pit to confirm the absence of soil contamination upgradient of the pit.

4.4 PROJECT SCHEDULE

The following schedule for the bioventing system upgrade is contingent upon approval of the Work Permit Request.

Event	Start Date	End Date	Duration (working days)
Submit Draft Corrective Action Plan and Design Package to AFCEE/ERT and Charleston AFB	NA	12 July 1996	NA
Charleston AFB Review Period	15 July 1996	27 Sept. 1996	55 days
Respond to Comments on Draft	30 Sept. 1996	1 Nov. 1996	25 days
Submit Draft Final CAP to AFCEE/ERT, Charleston AFB, USEPA ^{a/} , and SCDHEC ^{a/}	NA	4 Nov. 1996	NA
Draft Final Review Period	5 Nov. 1996	11 Dec. 1996	25 days
Respond to comments on Draft Final CAP	12 Dec. 1996	31 Dec. 1996	11 days
Final CAP and Design Package to AFCEE/ERT, Charleston AFB, and USEPA	NA	3 Jan. 1997	NA
Submit Work Permit (digging permit) Request	NA	3 Jan. 1997	NA
Construction of Expanded System/System Startup	13 Jan. 1997	24 Jan. 1997	10 days
Complete Construction Drawings/O&M Manual	27 Jan. 1997	7 March 1997	30 days

^{a/}Draft Final copies for USEPA and SCDHEC submitted by Charleston AFB.

4.5 SYSTEM OPERATION, MAINTENANCE, AND MONITORING

Following system installation, Parsons ES engineers will perform system startup and optimization. An O&M plan and as-built system drawings will be prepared and submitted to AFCEE and Charleston AFB. After the system has been optimized it will operate continuously until performance monitoring indicates that remedial objectives have been reached. At this time verification sampling will be performed, if required. The average of the biodegradation rates observed during one year of respiration testing (average of all three respiration tests) was 423 milligrams TPH per kilogram of soil per year. The highest TPH value detected in the bioventing test area was 2,200 mg/kg at MPD-3.9 (Table 3.1).

Confirmation soil sampling after one year of bioventing showed up to one order of magnitude TRPH reduction and the complete reduction of all soil BTEX compounds to below detection limits. Therefore, it is reasonable to assume that the expanded bioventing system has the capability to biodegrade the remaining BTEX compounds in unsaturated soils to below detection limits in a period of one to two years. This assumes that the bioventing is able to affect the targeted soils throughout the entire treatment period. Fluctuations in groundwater elevations may limit oxygen transport to contaminated soils at certain times of the year. Since there are no established ARAR/TBC levels for TRPH in soil, only a qualitative reduction of soil TRPH will be evaluated for this site to support a no further action site closure.

4.5.1 System Operation

At startup of the full-scale system, it will be necessary to optimize the air injection rate and to ensure proper operation of the blower system. Flow rate optimization is accomplished by gradually increasing the flow rate to each VW until soil gas oxygen concentrations at all VMPs reach a minimum concentration of approximately 5 percent. Oxygen levels in excess of 5 percent at the outer VMPs may indicate that the volume of air passing through the soil exceeds the biological oxygen utilization. The blower will be checked to ensure that it is producing the required flow rate and pressure for air injection.

Following flow rate optimization, the system shall run continuously and will require minimal maintenance as described below. Parsons ES has been contracted by AFCEE to provide one year of system operations and maintenance (O&M) support under Option 1 of the Extended Bioventing Program. O&M support will include performing system repairs should the bioventing system fail to operate properly.

4.5.2 System Maintenance

System maintenance requirements for the proposed bioventing system are minimal because the regenerative blowers are virtually maintenance-free. The only recurring maintenance required is a monthly check of the air filter, which is generally replaced when the vacuum across the inlet filter reaches a reading 10 to 15 inches of water greater than the reading with a clean filter. The time period between filter changes is dependent on site conditions, and is typically every three to six months. The O&M manual will further detail maintenance requirements. Parsons ES is responsible for one

year of maintenance support under Option 1 of the Extended Bioventing Project. Should the blower system give indications of an electrical or mechanical problem, such as a significant change in outlet pressure, abnormal noises from the blower, or system failure, during the first year of operation, Parsons ES will be responsible for repairing the system. Prior to mobilizing to the site, Parsons ES may request that a base electrician verify that adequate power is still being supplied to the blower motor. Once adequate power to the motor has been verified, Parsons ES will take the necessary actions to repair the blower system. Following the year of O&M support by Parsons ES, Charleston AFB will be responsible for system maintenance.

4.5.3 System Performance Monitoring

Routine monitoring of the bioventing system will include system checks of blower operation, including outlet pressures, inlet vacuum, and exhaust temperature every two weeks. These system checks will be performed by Charleston AFB personnel during and after the first year of operation.

To provide baseline data against which the progress of remediation can be evaluated, additional soil and soil gas samples will be collected during installation of the full-scale bioventing system. These data and the data collected during the pilot test project, the previous RFI studies, and the June 1996 soil gas survey will be used as a basis for evaluating effectiveness of the full-scale bioventing system.

Soil samples will be collected from all boreholes advanced during installation of the VMPs. Samples will be collected at 1-foot intervals, and will be screened in the field for organic vapors using a PID. Using the PID screening results as a guide to determine relative contamination, five soil samples will be sent to a South Carolina certified analytical laboratory for analysis of BTEX by Method SW8020, TRPH by Method SW8015 (modified), chlorinated hydrocarbons by Method SW8010, semi-volatile and polynuclear aromatic hydrocarbons (PAH) by Method SW8270, and eight RCRA metals by Method SW6010. Five soil samples will be collected from different boreholes for laboratory analyses if field screening indicates significant contamination is present at these locations.

Soil gas screening will be conducted with field instruments at all VMPs and VWs prior to system startup to establish baseline oxygen, carbon dioxide, and TVH levels. In addition, soil gas samples will be collected from five VMPs and will be forwarded to Air Toxics Ltd. of Folsom, California for analysis of TVH and BTEX by Method TO-3. The locations of these samples will be determined based on the field screening results. The five VMPs exhibiting the highest soil gas TVH concentrations (measured with field instruments) will be sampled for laboratory analysis.

System performance monitoring by Parsons ES under Option 1 of the Extended Bioventing Project will include *in situ* respiration testing during a site visit after one year of full-scale system operation. Soil gas samples will also be collected from the same five VMPs sampled during full-scale system installation and reanalyzed for BTEX and TVH using Method TO-3. No soil sampling will be performed under Option 1 of the Extended Bioventing Project. An Option 2 has been funded for this site that includes final confirmation soil sampling. The Option 2 closure soil sampling will be

initiated for this site when sampling indicators (i.e. soil gas and respiration data) indicate that significant reduction of hydrocarbons, especially the BTEX compounds, has occurred.

Prior to performing the 1-year respiration tests and soil gas sampling, the blowers will be turned off for 30 days to allow soil gas to equilibrate so that 1-year data can be compared to initial soil gas data. Air will be injected into VWs or VMPs for approximately 20 hours, and then shut off. Oxygen uptake will be monitored in the VMPs for approximately 72 hours to measure the rate at which oxygen decreases in the soil gas. These data will then be used to estimate the current biodegradation rates and to evaluate the progress of contaminant removal and system effectiveness. As the fuel in the soil is depleted, the respiration activity of the indigenous microorganisms is reduced, and slower oxygen utilization rates result. The use of oxygen utilization and soil gas chemistry as indicators of remaining contaminant concentration decreases the likelihood of premature closure soil sampling events.

System monitoring and *in situ* respiration test data will be analyzed to determine the progress of soil remediation. Estimates of contaminant reduction and time remaining to complete soil remediation will be based on the data collected during the respiration tests (oxygen utilization rates), quantitative estimates of the long-term biodegradation rates, and decreases in soil gas concentrations. If soil gas data indicate that the soils have been sufficiently remediated, closure soil sampling will be initiated under an Option 2.

Charleston AFB will be responsible for monitoring the bioventing system after the initial year of full-scale system operation is completed and prior to obtaining regulatory approval of a closure soil sampling and analysis plan (Option 2). It is recommended that annual respiration testing and soil gas sampling be performed to evaluate the progress of remediation until the closure sampling plan is approved and executed. Assuming that these monitoring activities are performed by a contractor, the annual cost to perform these activities is estimated as \$15,500. In addition to these activities, monitoring the system pressure, vacuum, and temperature should be performed every two weeks.

SECTION 5

HANDLING OF INVESTIGATION-DERIVED WASTES

Soil generated during excavation of the VW trench will be placed back into the trench for bioventing treatment to the extent practical. Any excess soil from this excavation will be containerized in 55-gallon drums and transported to a staging area designated by Charleston AFB. All soil cuttings generated during VMP soil boring installations will be containerized in 55-gallon drums and transported to the same staging area. Each drum will be clearly labeled as to its contents, site name, location, and date of generation. The volume of waste soil generated by these processes is expected to be minimal and will probably be less than four drums.

Waste disposal will be coordinated with the base according to base waste-handling procedures. Because this site is listed as a RCRA Solid Waste Management Unit, a comprehensive list of analyses may be required for acceptance at an appropriate waste disposal facility. It is anticipated that results of the laboratory analyses from the five environmental soil samples will adequately represent contaminant concentrations in the waste soils. Additionally, previous analytical data generated during the RFI can be used to further characterize soil contaminants that are expected to be present in wastes generated at this site. Additional waste characterization of drum composite samples will be performed if SCDHEC determines that the results of environmental samples are not acceptable to characterize the waste soils for disposal.

Decontamination of the backhoe bucket, augers, sampling equipment and other items requiring decontamination will be performed at a temporary decontamination area set up at the site. Decontamination water will be placed in a 55-gallon drum and then transported to an approved staging area. As with the waste soils, analyses of a composite sample will be performed if required by SCDHEC for off-base disposal. The volume of liquid wastes from decontamination is expected to be less than 30 gallons since there is minimal equipment that will be in contact with contaminated soils.

SECTION 6

BASE SUPPORT REQUIREMENTS

The following support from Charleston AFB is needed prior to arrival of the Parsons ES team and subcontractor(s) at the base:

- Assistance in obtaining a base digging permit.
- Obtaining all necessary regulatory permits and approvals for installation of the VWs, VMPs, and to conduct soil borings and sampling
- Assistance in obtaining an extension or amendment to the Underground Air Injection Control Permit from SCDHEC to allow construction and operation of the proposed new VW.
- Provide any paperwork required to obtain gate passes and security badges for subcontractor personnel and two Parsons ES employees. If required by the base, vehicle passes will be needed for two Parsons ES trucks and several subcontractor support trucks. These passes must be valid for the expected duration of VW installation (about 1 week) and the full-scale system installation and startup (about 3 weeks).
- A municipal water supply for well construction and decontamination activities.

During full-scale bioventing, base personnel will be required to check the blower systems once every two weeks to ensure that they are operating properly, record air injection pressures and temperatures, and replace air filters as needed. Parsons ES will provide a maintenance procedures manual and a brief training session.

1. If a blower stops working, notify Mr. Grant Watkins of Parsons ES - Cary at (919) 677-0080, Mr. John Ratz of Parsons ES - Denver at (303) 831-8100, or Capt. Ed Marchand of AFCEE at (210) 536-4364.
2. Arrange site access for a Parsons ES technician to conduct respiration testing and soil gas sampling approximately one year after full-scale system installation and start up.

SECTION 7

POINTS OF CONTACT

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SECTION 8

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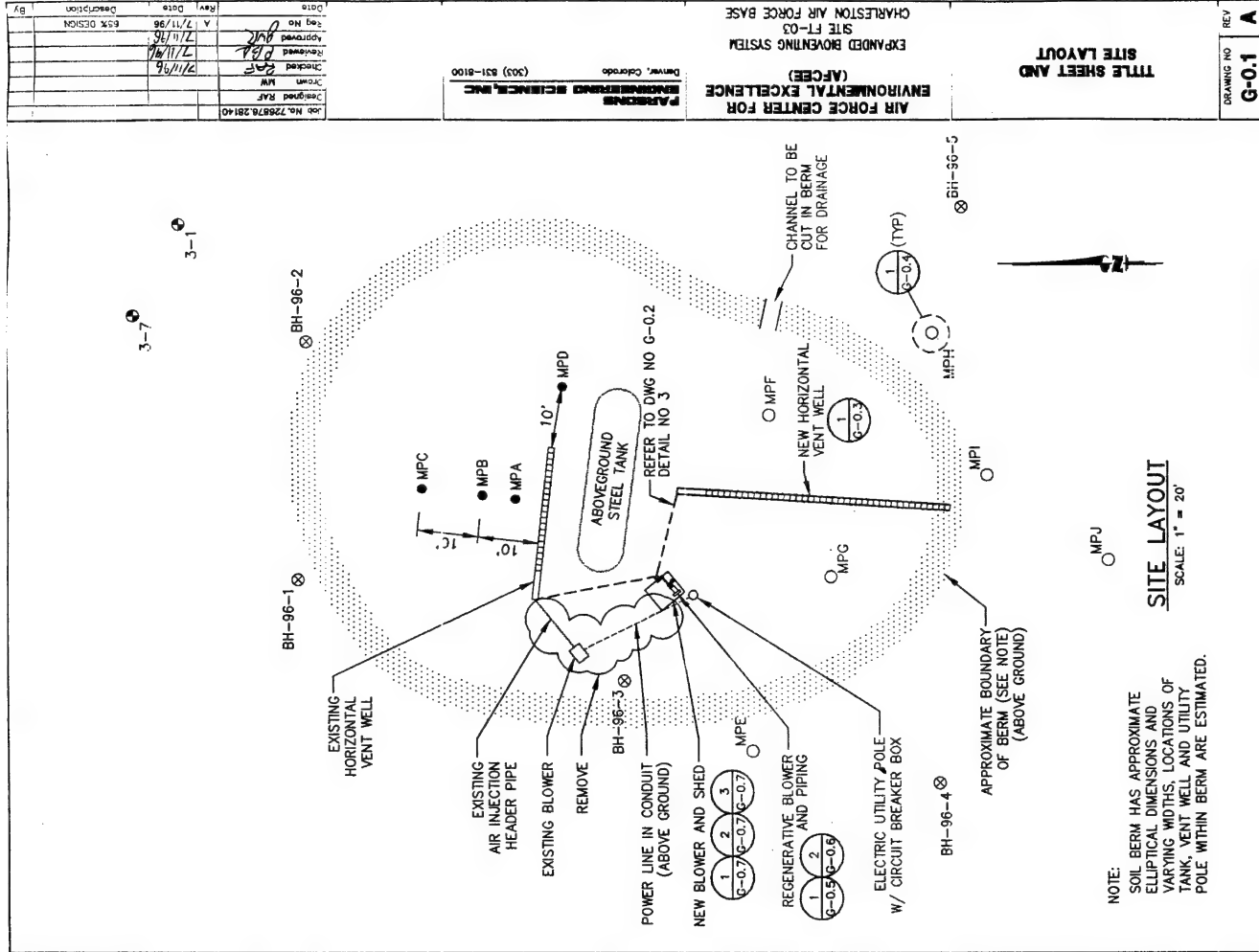
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- Hinchee, R.E., S.K. Ong, R.N. Miller, D.C. Downey, and R. Frandt. 1992. *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing.* January.
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APPENDIX A
DESIGN PACKAGE

CONSTRUCTION DRAWINGS FOR
EXPANDED BIOVENTING SYSTEM
SITE FT-03
CHARLESTON AIR FORCE BASE
 PREPARED FOR
AFCEE
JULY 1996

DRAWING INDEX

DRAWING NO.	DRAWING NAME
G-0.1	TITLE SHEET AND SITE LAYOUT
G-0.2	LEGEND AND STANDARD TRENCH DETAILS
G-0.3	VENT WELL STANDARD DETAIL
G-0.4	MONITORING POINT STANDARD DETAIL
G-0.5	BLOWER P & ID
G-0.6	BLOWER PIPING LAYOUT DETAIL
G-0.7	BLOWER SHED FIELD INSTALLATION DETAIL AND BLOWER SHED CONSTRUCTION DETAIL



Rev	Date	By	Description
1	7/11/96	AF	DESIGN
2	7/11/96	AF	DESIGN
3	7/11/96	AF	DESIGN
4	7/11/96	AF	DESIGN
5	7/11/96	AF	DESIGN
6	7/11/96	AF	DESIGN
7	7/11/96	AF	DESIGN
8	7/11/96	AF	DESIGN
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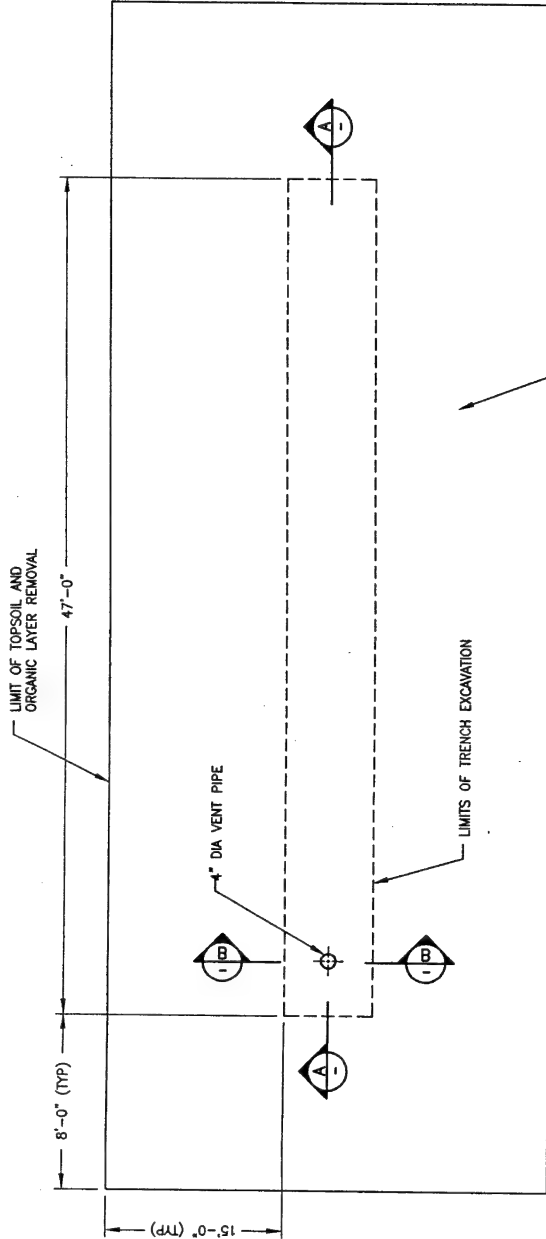
Job No. 725078.28140	Drawn: MAF	Checked: MAF	Reviewed: MAF	Approved: MAF	Reg. No. 7/11/96	Date: 7/11/96	Rev: 1
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PARSONS ENGINEERING & CONSTRUCTION, INC.	Denver, Colorado	(303) 831-8100
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AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE (AFCEE)	EXPANDED BIOVENT SYSTEM	SITE FT-CO	CHARLESTON AIR FORCE BASE
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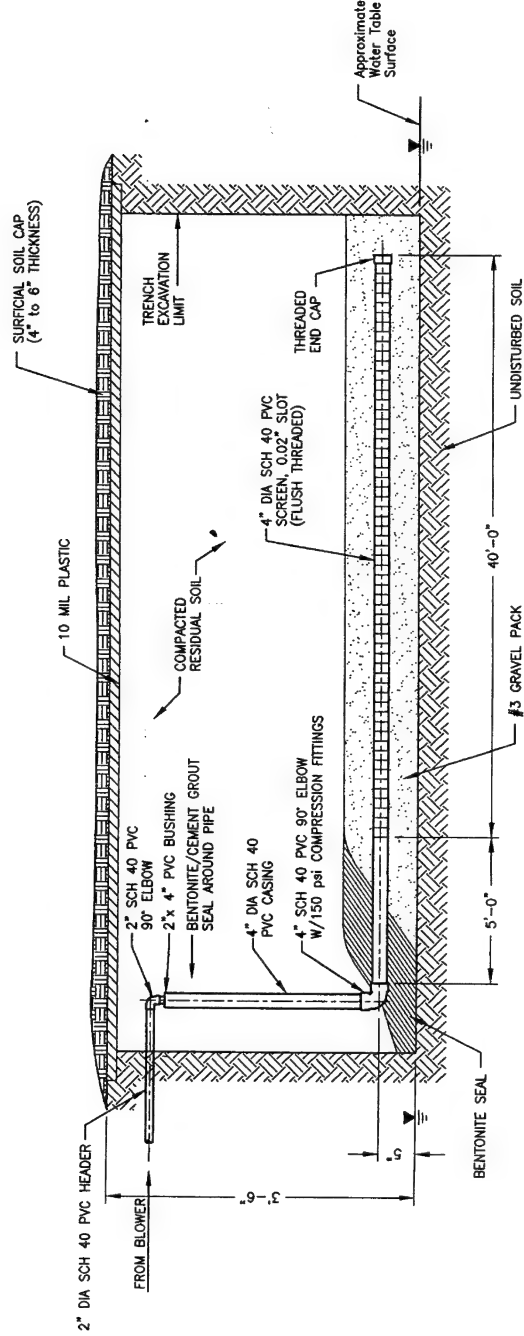
STANDARD DETAIL	VENT WELL
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DRAWING NO. G-0.3	REV. A
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10 MIL POLYETHYLENE SHEETING
OVERLAIN BY 4" TO 6" OF SURFACE
SOIL SLOPED TOWARDS EDGES

VENT WELL (VW) DETAIL

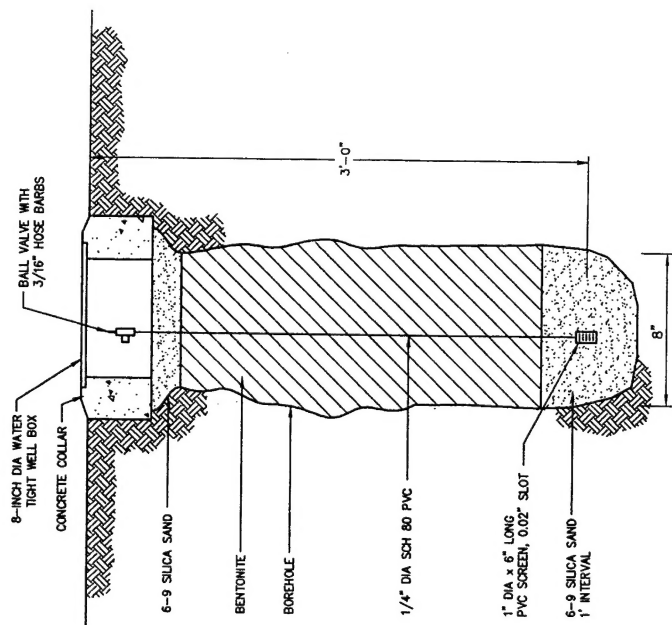


SECTION A-A

SECTION B-B

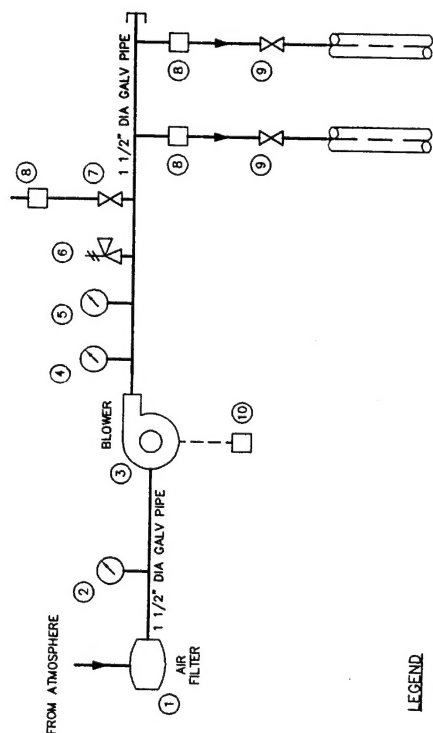
NOTES:

1. DRAWING IS NOT TO SCALE.
2. POLYETHYLENE SHEETING SHALL BE OVERLAPPED BY 5 FEET WHERE REQUIRED.



MONITORING POINT (MP) DETAIL

SCALE: NTS



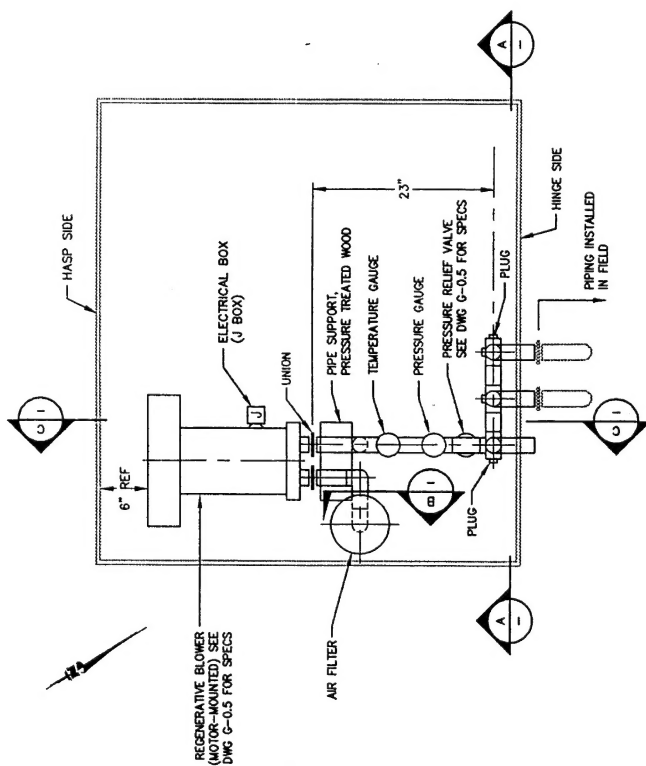
LEGEND

- ① INLET AIR FILTER - SOLBERG F-30P-150, REPLACEMENT ELEMENT 30P
- ② VACUUM GAUGE - GAST[®] AM487, 2 5/8" DIA., 0-60" H₂O, 1/4" NPT, LM
(Part No. AA497)
- ③ BLOWER - GAST[®] 1.5 HP R4P140N-50, 72 CFM AT 40" H₂O PRESSURE
- ④ TEMPERATURE GAUGE - ASHCROFT, 0-250°F, 1/2" NPT, CBM
(Part No. 2A606 FROM GRANNER)
- ⑤ PRESSURE GAUGE - WKA 611.10, 2 1/2" DIA., 0-100" H₂O, 1/4" NPT, CBM
(Part No. 985187g)
- ⑥ AUTOMATIC PRESSURE RELIEF VALVE - GAST AG258, SET TO RELEASE AT 50" H₂O PRESSURE
- ⑦ MANUAL PRESSURE RELIEF (BLED) VALVE - 1 1/2" GATE
- ⑧ FLOW MEASURING PORT FITTED WITH PLUG (1/4"x 1/8" NPT BRASS REDUCING BUSHING, 1/8" NPT BRASS PLUG)
- ⑨ FLOW CONTROL VALVE - 1 1/2" GATE
- ⑩ FUSED DISCONNECT SWITCH

BLOWER PIPING AND INSTRUMENTATION DIAGRAM

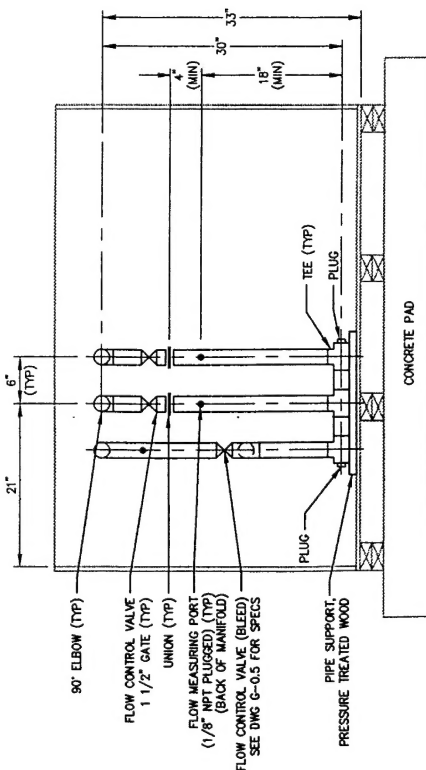
SCALE: NTS

- NOTES:
1. SHOP CORE HOLES TO PIPING DIMENSIONS
 2. ALL PIPING 1 1/2" DIA. GALVANIZED STEEL UNLESS OTHERWISE NOTED
 3. SEE DRAWING G-07 FOR BLOWER BUILDING DETAILS



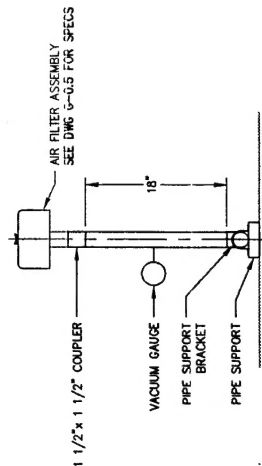
BLOWER PIPING LAYOUT PLAN DETAIL

3/4" = 1'-0"



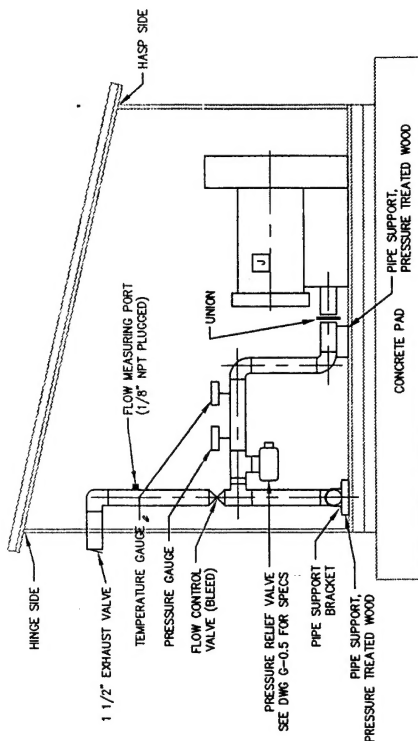
MANIFOLD DETAIL SECTION

3/4" = 1'-0"



BLOWER INLET PIPING SECTION

3/4" = 1'-0"



BLOWER OUTLET PIPING SECTION

3/4" = 1'-0"

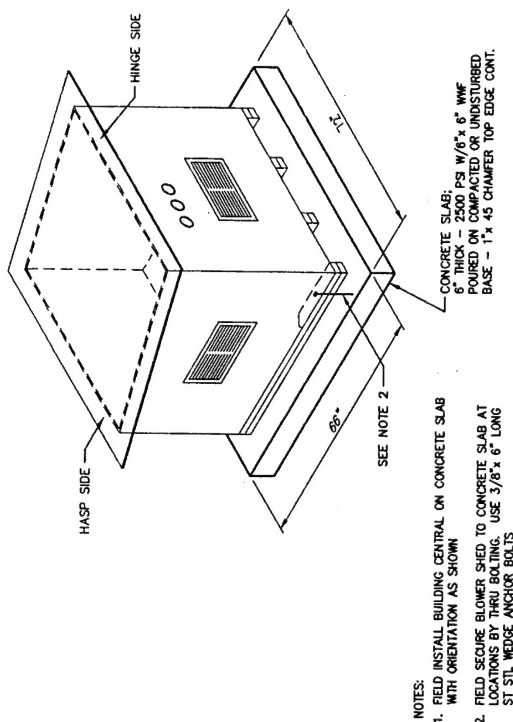
Rev	Date	By
1	7/11/96	AFCE
2	7/11/96	AFCE
3	7/11/96	AFCE
4	7/11/96	AFCE
5	7/11/96	AFCE
6	7/11/96	AFCE
7	7/11/96	AFCE
8	7/11/96	AFCE
9	7/11/96	AFCE
10	7/11/96	AFCE

Job No. 726876.20140	Drawn: MAF	Checked: MAF	Approved: MAF	Date: 7/11/96
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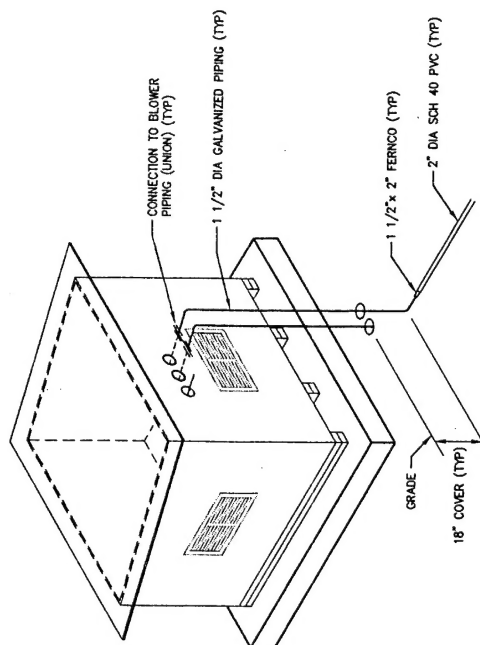
AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE (AFCEE)	EXPANDED BLOWING SYSTEM SITE FT-03 CHARLESTON AIR FORCE BASE
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BLOWER PIPING LAYOUT DETAIL	DRAWING NO. G-0.6	REV. A
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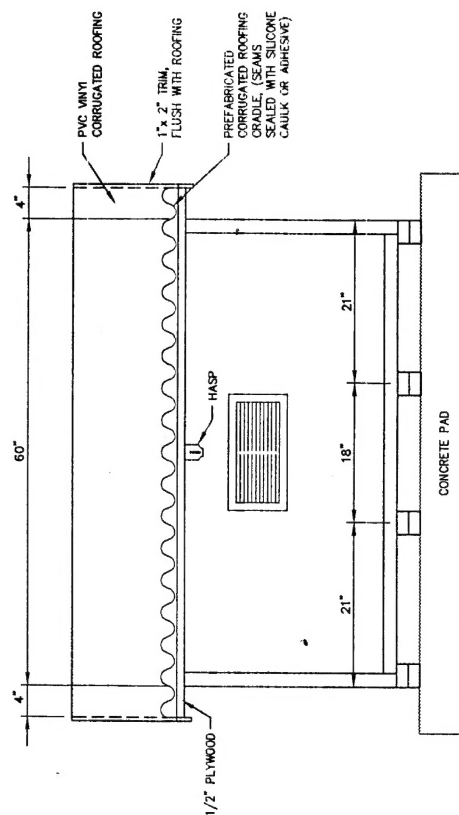
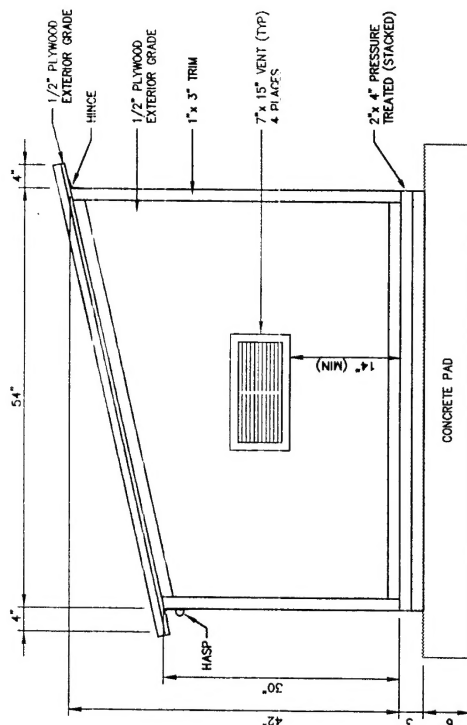


BLOWER SHED FIELD INSTALLATION DETAIL

NOT TO SCALE



NOT TO SCALE



- NOTES:

1. 2"x 2" FRAME CONSTRUCTION
2. FLOOR CONSTRUCTED OF 3/4" EXTERIOR GRADE PLYWOOD
3. ROOF CONSTRUCTED OF 1/2" EXTERIOR GRADE PLYWOOD COVERED WITH PVC VINYL CORRUGATED ROOFING

BLOWER SHED CONSTRUCTION DETAIL

 $3/4" = 1'-0"$

Date	Rev	Date	Description
Job No. 726878.20140	Designated RAF		
Drawing MW			
Checked EAF		7/11/94	
Reviewed EAF		7/11/94	
Approved MW		7/11/96	
Reg No	A	7/11/96	65% DESIGN

ATLAS ENGINEERING AND SCIENCE, INC.
Denver, Colorado (303) 831-8100

AIR FORCE CENTER FOR
ENVIRONMENTAL EXCELLENCE
(AFCEE)
EXPANDED BIOVENTING SYSTEM
SITE FT-03
CHARLESTON AIR FORCE BASE

**BLOWER SHED FIELD
INSTALLATION DETAIL
AND BLOWER SHED
CONSTRUCTION DETAILS**

DRAWING NO. **G-0.7** REV **A**